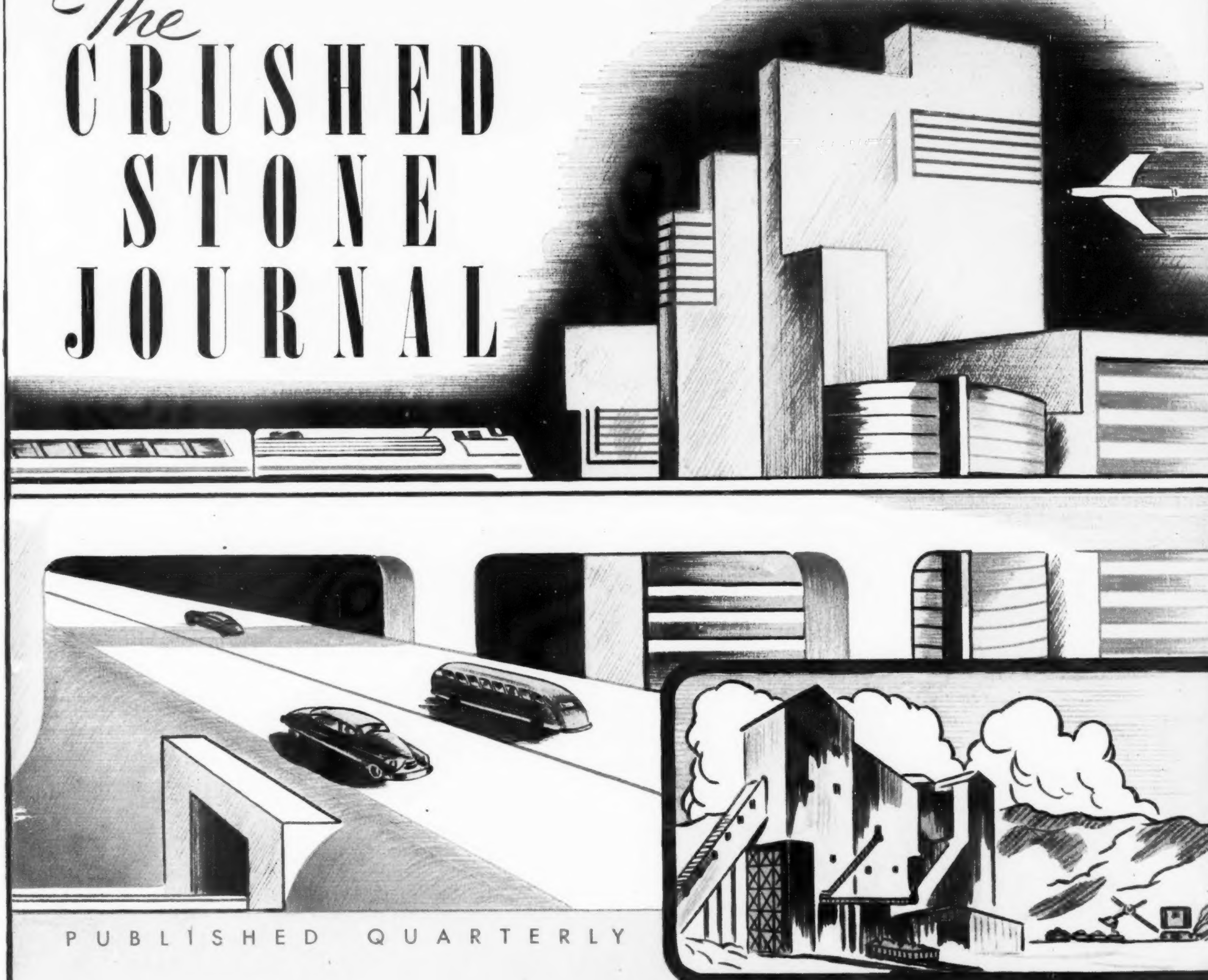
The CRUSHED STONE JOURNAL



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The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

NATIONAL CRUSHED STONE ASSOCIATION

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THE
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Awards of the Silver Anniversary Safety Competition of the National Crushed Stone Association

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THE over-all injury experience at crushed stone operations participating in the National Crushed Stone Association Safety Competition of 1950 was one of the best in the 25-year history of the contest according to the Bureau of Mines, United States Department of the Interior. Although the injury record of the competing operations has not been improved in each competition year, there has been a very definite long term improvement shown over the 25-year span of the contest. The injury severity rate of 3.874 days lost per 1,000 man-hours of work during 1950 represents a favorable reduction of 29 per cent from the corresponding severity experience of 5.462 in the first competition of 1926. The long term improvement in injury frequency is more marked than that shown by the severity rate. In 1950, injury frequency was 24.828 per million man-hours, a 42 per cent improvement over the frequency of 42.978 in 1926 when the safety competition was started. These long term improvements in over-all records of the participating plants are indications of the usefulness of safety contests which add the incentive of the competitive spirit into accident-prevention work.

Winning Plant

Highest safety honors in the 1950 National Crushed Stone Association Safety Competition were won by the Columbia No. 1 quarry of the Columbia Quarry Company at Columbia, Illinois. This limestone quarry won the bronze plaque provided by the Explosives Engineer Magazine for the outstanding accomplishment of being operated 228,758 man-hours without a lost-time disabling injury during 1950. The award in 1950 was the fourth time that this plant has had the best safety record of the competing operations. It previously had won the bronze trophy in 1935, 1936, and 1937. In addition the quarry has been awarded Certificates of Honorable Mention for injury-free operations in 1933, 1934, and 1938. The Columbia No. 1 quarry has been enrolled in the competition in each of the past 20 years. During this period the quarry had the remarkable safety record of being operated for 6 consecutive years, 1933-38, without any disabling injuries during an aggregate worktime of 1,188,544 man-hours. The outstanding safety achievements in 1950 and in the past are clear evidence that the men of the Columbia No. 1 quarry are cooperating closely in carrying on an effective safety program designed to promote safe working practices and conditions. The contribution of each man at the quarry to the success of the group in eliminating injuries through 1950 is recognized by the award of individual certificates to the men by the National Crushed Stone Association.

The Kimballton underground limestone mine of The Standard Lime and Stone Company at Kimballton, Virginia ranked in second place in the 1950 contest with the outstanding achievement of being worked 172,964 man-hours without any injuries. The No. 1 quarry of the Callanan Road Improvement Company at South Bethlehem, New York, was ranked in third place in the competition with its safety accomplishment of 115,412 man-hours of worktime without any disabling injuries.

TABLE I

RELATIVE STANDING OF QUARRIES IN THE 1950 NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, BASED UPON THE INJURY-SEVERITY RATES OF THE QUARRIES [1]

Rank	Man-hours worked	Number of injuries [2]					Average days of disability per temp. injury	Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
		F.	P.T.	P.P.	Temp.	Total		F.	P.T.	P.P.	Temp.	Total		
1	228,758	—	—	—	—	—	—	—	—	—	—	—	0.000	0.000
3	115,412	—	—	—	—	—	—	—	—	—	—	—	.000	.000
4	95,890	—	—	—	—	—	—	—	—	—	—	—	.000	.000
5	88,433	—	—	—	—	—	—	—	—	—	—	—	.000	.000
6	82,495	—	—	—	—	—	—	—	—	—	—	—	.000	.000
7	74,075	—	—	—	—	—	—	—	—	—	—	—	.000	.000
8	71,588	—	—	—	—	—	—	—	—	—	—	—	.000	.000
9	68,848	—	—	—	—	—	—	—	—	—	—	—	.000	.000
10	64,295	—	—	—	—	—	—	—	—	—	—	—	.000	.000
11	53,683	—	—	—	—	—	—	—	—	—	—	—	.000	.000
12	45,112	—	—	—	—	—	—	—	—	—	—	—	.000	.000
13	35,759	—	—	—	—	—	—	—	—	—	—	—	.000	.000
14	27,072	—	—	—	—	—	—	—	—	—	—	—	.000	.000
15	26,416	—	—	—	—	—	—	—	—	—	—	—	.000	.000
16	12,398	—	—	—	—	—	—	—	—	—	—	—	.000	.000
17	93,956	—	—	—	1	1	3	—	—	—	3	3	10.643	.032
18	457,829	—	—	—	1	1	67	—	—	—	67	67	2.184	.146
19	64,788	—	—	—	1	1	11	—	—	—	11	11	15.435	.170
20	173,400	—	—	—	4	4	12	—	—	—	49	49	23.068	.283
21	384,266	—	—	—	5	5	29	—	—	—	143	143	13.012	.372
22	166,313	—	—	—	3	3	26	—	—	—	77	77	18.038	.463
23	115,480	—	—	—	3	3	20	—	—	—	60	60	25.979	.520
24	258,038	—	—	—	9	9	17	—	—	—	152	152	34.879	.589
25	332,730	—	—	—	12	12	18	—	—	—	218	218	36.065	.655
26	212,804	—	—	—	5	5	30	—	—	—	150	150	23.496	.705
27	55,000	—	—	—	1	1	40	—	—	—	40	40	18.182	.727
28	142,883	—	—	—	7	7	18	—	—	—	128	128	48.991	.890
29	120,230	—	—	—	7	7	18	—	—	—	123	123	58.222	1.023
31	330,348	—	—	1	21	22	12	—	—	104	259	363	66.596	1.099
32	133,344	—	—	—	8	8	18	—	—	—	147	147	59.995	1.102
33	73,987	—	—	—	2	2	42	—	—	—	84	84	27.032	1.135
35	30,880	—	—	—	1	1	39	—	—	—	39	39	32.383	1.263
36	154,770	—	—	1	6	7	12	—	—	150	71	221	45.228	1.428
37	172,364	—	—	1	3	4	38	—	—	150	113	263	23.207	1.526
39	80,805	—	—	—	1	1	127	—	—	—	127	127	12.375	1.572
40	41,340	—	—	—	4	4	16	—	—	—	65	65	96.759	1.572
41	68,746	—	—	—	1	1	140	—	—	—	140	140	14.546	2.036
42	17,192	—	—	—	3	3	14	—	—	—	41	41	174.500	2.385
43	41,782	—	—	—	2	2	67	—	—	—	133	133	47.868	3.183
44	671,050	—	—	2	25	27	23	—	—	2,550	565	3,115	40.235	4.642
45	81,371	—	—	—	8	8	58	—	—	—	467	467	98.315	5.739
46	50,122	—	—	1	1	2	2	—	—	300	2	302	39.903	6.025
47	748,681	1	—	—	1	2	270	6,000	—	—	270	6,270	2.671	8.375
49	63,840	—	—	1	5	6	15	—	—	600	75	675	93.985	10.573
51	81,600	1	—	—	2	3	3	6,000	—	—	6	6,006	36.765	73.603
Totals and rates 1950	6,510,173	2	—	7	153	162	25	12,000	—	3,854	3,825	19,679	24.884	3.023
1949	7,166,644	3	—	11	153	167	22	18,000	—	9,465	3,345	30,810	23.302	4.299

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed.

[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability.

[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates number of days of disability lost from injuries per thousand man-hours of exposure.

Injury-Free Operations

The following fifteen plants of which one is an underground mine attained injury-free records in 1950 and were awarded Certificates of Honorable Mention by the National Crushed Stone Association. Including the trophy winner, the sixteen injury-free operations were worked a total of 1,263,198 man-hours which represents 17 per cent of the total man-hours worked at all 51 competing plants. Such accomplishments result only from persistent and well directed efforts aimed at the elimination of all accidents from daily work.

Kimballton lime mine, The Standard Lime and Stone Company, Kimballton, Giles County, Virginia; 172,964 man-hours.

Plant No. 1 limestone quarry, Callanan Road Improvement Company, South Bethlehem, Albany County, New York; 115,412 man-hours.

North Branford No. 7 trap rock quarry, The New Haven Trap Rock Company, North Branford, New Haven County, Connecticut; 95,890 man-hours.

Gibsonburg lime and limestone quarry, The Kelley Island Lime and Transport Company, Gibsonburg, Sandusky County, Ohio; 88,433 man-hours.

Watertown limestone quarry, The General Crushed Stone Company, Watertown, Jefferson County, New York; 82,495 man-hours.

Martha limestone quarry, Marquette Cement Manufacturing Company, Lebanan, Wilson County, Tennessee; 74,075 man-hours.

Oriskany Falls limestone Plant No. 5 quarry, Eastern Rock Products, Incorporated, Oriskany Falls, Oneida County, New York; 71,588 man-hours.

Auburn limestone quarry, The General Crushed Stone Company, Auburn, Cayuga County, New York; 68,848 man-hours.

Jordanville limestone quarry, The General Crushed Stone Company, Jordanville, Herkimer County, New York; 64,295 man-hours.

Middlefield No. 1 trap rock quarry, The New Haven Trap Rock Company, Middlefield, New Haven County, Connecticut; 53,683 man-hours.

Marquette limestone quarry, Marquette Cement Manufacturing Company, Cape Girardeau, Cape Girardeau County, Missouri; 45,112 man-hours.

Plant No. 4 trap rock quarry, Southwest Stone Company, Knippa, Uvalde County, Texas; 35,759 man-hours.

Prospect limestone Plant No. 6 quarry, Eastern Rock Products, Incorporated, Prospect, Oneida County, New York; 27,072 man-hours.

McCoy limestone quarry, Warner Company, Bridgeport, Montgomery County, Pennsylvania; 26,416 man-hours.

Pearisburg hydrated lime quarry, Ripplemead Lime Company, Incorporated, Ripplemead, Giles County, Virginia; 12,398 man-hours.

Statistics of the Competition

Injury-experience of the 51 operations participating in the silver anniversary competition of 1950 was better than the average for the 25 years of the contest. The injury severity rate of 3.874 days lost per 1,000 man-hours of work was the sixth lowest annual rate and was 31 per cent below the average rate for the history of the contest. Injury frequency at the competing operations of 24.828 disabling injuries per 1,000,000 man-hours in 1950 was the eighth lowest annual rate and was 19 per cent better than the average rate for the 25 years. However, the experience in 1950 was changed very slightly from that in the 1949 competition. The injury severity rate was slightly improved over that of 3.949 days lost per 1,000 man-hours in the 1949 contest. On the other hand, the injury frequency in 1950 was slightly less favorable than that of 22.704 injuries per 1,000,000 man-hours in the 1949 contest.

A total of 7,612,446 man-hours was worked at the operations enrolled in the 1950 National Crushed Stone Association Safety Competition. During this worktime, there were a total of 189 disabling injuries of which 3 were fatalities, 8 were permanent partial disabilities and 178 were temporary total disabilities. The average disability of the 178 temporary total injuries was 26 days per disability, an increase of 4 days over the corresponding figure of 22 days in 1949.

Of the operations enrolled in the 1950 contest, 45 were open quarries and 6 were underground mines. Injury experience in the 45 quarries was a severity

TABLE II

RELATIVE STANDING OF UNDERGROUND MINES IN THE 1950 NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, BASED UPON THE INJURY-SEVERITY RATES OF THE MINES [1]

Rank	Man-hours worked	Number of injuries [2]					Average days of disability per temp. injury	Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
		F.	P. T.	P. P.	Temp.	Total		F.	P. T.	P. P.	Temp.	Total		
2	172,964	—	—	—	—	—	—	—	—	—	—	—	0.000	0.000
30	109,957	—	—	—	6	6	20	—	—	—	119	119	54.567	1.082
34	353,107	—	—	—	3	3	141	—	—	—	422	422	8.496	1.195
38	25,660	—	—	—	2	2	20	—	—	—	40	40	77.942	1.559
48	302,366	—	—	1	8	9	13	—	—	3,000	100	3,100	29.765	10.252
50	138,219	1	—	—	6	7	22	6,000	—	—	129	6,129	50.644	44.343
Totals and rates, 1950	1,102,273	1	—	1	25	27	32	6,000	—	3,000	810	9,810	24.495	8.900
1949,	981,692	—	—	1	17	18	27	—	—	900	467	1,367	18.336	1.392

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed.

[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability.

[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates number of days of disability lost from injuries per thousand man-hours of exposure.

TABLE III

YEARLY SUMMARY—QUARRIES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION 1926–50 [1]

Year	Plants	Man-hours worked	Number of injuries [2] Fatal	P. T.	P. P.	Temp.	Total	Number of days of disability [2] Fatal	P. T.	P. P.	Temp.	Total	Frequency rate [3]	Severity rate [3]
1926	40	5,298,983	3	—	6	207	216	18,000	—	9,000	4,239	31,239	40.763	5.895
1927	48	7,876,791	9	—	2	458	469	54,000	—	2,100	7,186	63,286	59.542	8.034
1928	53	7,509,098	8	—	4	322	334	48,000	—	8,700	5,493	62,193	44.479	8.282
1929	53	7,970,325	4	—	5	286	295	24,000	—	5,760	5,533	35,293	37.012	4.428
1930	68	8,013,415	6	—	9	227	242	36,000	—	7,250	3,671	46,921	30.199	5.855
1931	58	5,085,857	4	—	13	198	215	24,000	—	18,660	3,540	46,200	42.274	9.084
1932	40	2,661,850	1	—	4	75	80	6,000	—	6,750	2,481	15,231	30.054	5.722
1933	40	2,704,871	1	—	1	67	69	6,000	—	48	2,893	8,941	25.510	3.306
1934	46	3,288,257	1	—	2	106	109	6,000	—	2,850	1,873	10,723	33.148	3.261
1935	46	4,166,306	2	1	8	77	88	12,000	6,000	9,900	3,015	30,915	21.122	7.420
1936	50	6,399,023	5	—	14	182	201	30,000	—	8,168	4,590	42,758	31.411	6.682
1937	47	6,199,001	7	—	9	136	152	42,000	—	5,875	4,461	52,336	24.520	8.443
1938	47	4,658,119	2	—	6	76	84	12,000	—	6,600	3,184	21,784	18.033	4.677
1939	44	4,219,086	2	—	2	51	55	12,000	—	4,800	1,678	18,478	13.036	4.380
1940	46	4,358,409	1	—	5	78	84	6,000	—	2,550	3,013	11,563	19.273	2.653
1941	47	5,777,587	3	—	5	98	106	18,000	—	9,300	2,266	29,566	18.347	5.117
1942	48	7,178,935	3	2	1	183	189	18,000	12,000	1,500	4,239	35,739	26.327	4.978
1943	34	4,750,314	4	—	5	134	143	24,000	—	7,146	3,862	35,008	30.103	7.370
1944	32	3,996,433	3	—	4	118	125	18,000	—	3,000	3,323	24,323	31.278	6.086
1945	46	6,087,037	—	—	1	135	136	—	—	750	3,505	4,255	22.343	0.699
1946	46	7,292,175	1	—	6	197	204	6,000	—	5,141	4,130	15,271	27.975	2.094
1947	42	6,971,790	5	—	5	197	207	30,000	—	6,900	4,990	41,890	29.691	6.008
1948	47	6,953,569	4	—	11	181	196	24,000	—	8,018	4,642	36,660	28.187	5.272
1949	57	7,166,644	3	—	11	153	167	18,000	—	9,465	3,345	30,810	23.302	4.299
1950	45	6,510,173	2	—	7	153	162	12,000	—	3,854	3,825	19,679	24.884	3.023
Total	—	143,094,048	84	3	146	4,095	4,328	504,000	18,000	154,085	94,977	771,062	30.246	5.388

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed.
[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability.
[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates number of days of disability lost from injuries per thousand man-hours of exposure.

TABLE IV

YEARLY SUMMARY—UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1926–1950 [1]

Year	Plants	Man-hours worked	Number of injuries [2] Fatal	P. T.	P. P.	Temp.	Total	Number of days of disability [2] Fatal	P. T.	P. P.	Temp.	Total	Frequency rate [3]	Severity rate [3]
1926	3	517,926	—	—	—	34	34	—	—	—	533	533	65.646	1.029
1927	2	318,449	1	—	1	14	16	6,000	—	300	68	6,368	50.244	19.997
1928	5	542,193	1	—	1	68	70	6,000	—	300	888	7,188	129.105	13.257
1929	4	665,520	1	—	1	30	32	6,000	—	300	617	6,917	48.083	10.393
1930	6	595,367	1	—	1	15	17	6,000	—	225	468	6,693	28.554	11.242
1931	3	345,105	—	—	—	4	4	—	—	—	147	147	11.591	.426
1932	2	158,450	—	—	—	6	6	—	—	—	165	165	37.867	1.041
1933	3	229,381	—	—	—	11	11	—	—	—	349	349	47.955	1.521
1934	4	248,146	—	—	—	13	13	—	—	—	287	287	52.389	1.157
1935	2	175,994	—	—	—	3	3	—	—	—	249	249	17.046	1.415
1936	4	334,747	1	—	—	7	8	6,000	—	—	117	6,117	23.899	18.274
1937	3	364,680	—	—	—	3	3	—	—	—	91	91	8.226	.250
1938	3	334,442	—	—	—	2	2	—	—	—	133	133	5.980	.398
1939	4	393,039	—	—	1	7	8	—	—	600	457	1,057	20.354	2.689
1940	4	375,987	—	—	1	8	9	—	—	4,500	888	5,388	23.937	14.330
1941	4	591,568	—	—	1	15	16	—	—	750	169	919	27.047	1.553
1942	4	785,894	—	—	1	33	34	—	—	1,800	1,213	3,013	43.263	3.834
1943	5	1,019,771	—	—	3	45	48	—	—	4,950	1,123	6,073	47.069	5.955
1944	4	727,496	1	—	1	27	29	6,000	—	2,400	796	9,196	39.863	12.641
1945	7	1,238,845	—	—	2	22	24	—	—	3,000	755	3,755	19.373	3.031
1946	8	1,338,563	2	—	2	31	35	12,000	—	675	1,045	13,720	26.147	10.250
1947	8	1,291,162	5	—	1	29	35	30,000	—	75	1,588	31,663	27.107	24.523
1948	4	940,031	—	—	—	16	16	—	—	—	935	935	17.021	.995
1949	5	981,692	—	—	1	17	18	—	—	900	467	1,367	18.336	1.392
1950	6	1,102,273	1	—	1	25	27	6,000	—	3,000	810	9,810	24.495	8.900
Total	—	15,616,721	14	—	19	485	518	84,000	—	23,775	14,358	122,133	33.170	7.821

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed.
[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability.
[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates number of days of disability lost from injuries per thousand man-hours of exposure.

TABLE V

YEARLY SUMMARY—QUARRIES AND UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1926-50 [1]

Year	Plants	Man-hours worked	Number of injuries [2]					Number of days of disability [2]					Frequency rate [3]	Severity rate [3]
			Fatal	P. T.	P. P.	Temp.	Total	Fatal	P. T.	P. P.	Temp.	Total		
1926	43	5,816,909	3	—	6	241	250	18,000	—	9,000	4,772	31,772	42.978	5.462
1927	50	8,195,240	10	—	3	472	485	60,000	—	2,400	7,254	69,654	59.181	8.499
1928	58	8,051,291	9	—	5	390	404	54,000	—	9,000	6,381	69,381	50.178	8.617
1929	57	8,635,845	5	—	6	316	327	30,000	—	6,060	6,150	42,210	37.865	4.888
1930	74	8,608,782	7	—	10	242	259	42,000	—	7,475	4,139	53,614	30.086	6.228
1931	61	5,430,962	4	—	13	202	219	24,000	—	18,660	3,687	46,347	40.324	8.534
1932	42	2,820,300	1	—	4	81	86	6,000	—	6,750	2,646	15,396	30.493	5.459
1933	43	2,934,252	1	—	1	78	80	6,000	—	48	3,242	9,290	27.264	3.166
1934	50	3,536,403	1	—	2	119	122	6,000	—	2,850	2,160	11,010	34.498	3.113
1935	48	4,342,300	2	1	8	80	91	12,000	6,000	9,900	3,264	31,164	20.957	7.177
1936	54	6,733,770	6	—	14	189	209	36,000	—	8,168	4,707	48,875	31.038	7.258
1937	50	6,563,681	7	—	9	139	155	42,000	—	5,875	4,552	52,427	23.615	7.987
1938	50	4,992,561	2	—	6	78	86	12,000	—	6,600	3,317	21,917	17.226	4.390
1939	48	4,612,125	2	—	3	58	63	12,000	—	5,400	2,135	19,535	13.660	4.236
1940	50	4,734,396	1	—	6	86	93	6,000	—	7,050	3,901	16,951	19.643	3.580
1941	51	6,369,155	3	—	6	113	122	18,000	—	10,050	2,435	30,485	19.155	4.786
1942	52	7,964,829	3	2	2	216	223	18,000	12,000	3,300	5,452	38,752	27.998	4.865
1943	39	5,770,085	4	—	8	179	191	24,000	—	12,096	4,985	41,081	33.102	7.120
1944	36	4,723,929	4	—	5	145	154	24,000	—	5,400	4,119	33,519	32.600	7.096
1945	53	7,325,882	—	—	3	157	160	—	—	3,750	4,260	8,010	21.840	1.093
1946	54	8,630,738	3	—	8	228	239	18,000	—	5,816	5,175	28,991	27.692	3.359
1947	50	8,262,952	10	—	6	226	242	60,000	—	6,975	6,578	73,553	29.287	8.902
1948	51	7,893,600	4	—	11	197	212	24,000	—	8,018	5,577	37,595	26.857	4.763
1949	62	8,148,336	3	—	12	170	185	18,000	—	10,365	3,812	32,177	22.704	3.949
1950	51	7,612,446	3	—	8	178	189	18,000	—	6,854	4,635	29,489	24.828	3.874
Total	—	158,710,769	98	3	165	4,580	4,846	588,000	18,000	177,860	109,335	893,195	30.534	5.628

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed.

[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability.

[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates number of days of disability lost from injuries per thousand man-hours of exposure.

TABLE VI

NUMBER OF INJURIES, BY CAUSES, AT QUARRIES AND UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION IN 1950

Cause	Fatal	Permanent		Temporary	Total
		Total	Partial		
Falls and slides of rock or materials	1	—	—	18	19
Handling materials or objects	—	—	2	23	25
Hand tools	—	—	—	10	10
Explosives	—	—	—	1	1
Haulage	—	—	2	21	23
Falls of persons	—	—	—	26	26
Bumping against objects	—	—	—	5	5
Falling objects	1	—	—	12	13
Flying objects or particles	—	—	—	11	11
Electricity	1	—	—	7	8
Drilling	—	—	—	6	6
Machinery	—	—	4	12	16
Stepping on objects	—	—	—	9	9
Burns	—	—	—	4	4
Other causes	—	—	—	4	4
Total	3	—	8	169	180
Not stated	—	—	—	9	9
Grand total	3	—	8	178	189

TABLE VII

DAYS OF DISABILITY, BY CAUSES, OF INJURIES AT QUARRIES AND UNDERGROUND MINES IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION IN 1950

Cause	Fatal	Permanent		Temporary	Total
		Total	Partial		
Falls and slides of rock or materials	6,000	—	—	600	6,600
Handling materials or objects	—	—	300	459	759
Hand tools	—	—	—	222	222
Explosives	—	—	—	17	17
Haulage	—	—	3,000	762	3,762
Falls of persons	—	—	—	1,006	1,006
Bumping against objects	—	—	—	21	21
Falling objects	6,000	—	—	147	6,147
Flying objects or particles	—	—	—	476	476
Electricity	6,000	—	—	114	6,114
Drilling	—	—	—	112	112
Machinery	—	—	3,554	349	3,903
Stepping on objects	—	—	—	32	32
Burns	—	—	—	34	34
Other causes	—	—	—	156	156
Total	18,000	—	6,854	4,507	29,361
Not stated	—	—	—	128	128
Grand total	18,000	—	6,854	4,635	29,489

rate of 3.023 which was the fourth lowest annual rate for open quarries in the history of the competition. It represented a sharp improvement over the corresponding rate of 4.299 days lost per 1,000 man-hours for the 57 open quarries in the 1949 competition. The injury frequency of the open quarries in 1950 was 24.884 per 1,000,000 man-hours, slightly less favorable than the comparable rate for 1949.

TABLE VIII

NUMBER AND PERCENTAGE DISTRIBUTION OF INJURIES AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1948-50, BY CAUSES

Causes	1948		1949		1950		Total	
	Number	Per cent of total	Number	Per cent of total	Number	Per cent of total	Number	Per cent of total
Falls and slides of rock	12	6.9	16	9.0	19	10.6	47	8.8
Handling materials	36	20.7	10	5.6	25	13.9	71	13.4
Hand tools	19	10.9	18	10.1	10	5.6	47	8.8
Explosives	1	.6	4	2.2	1	.6	6	1.1
Haulage	27	15.5	25	14.1	23	12.8	75	14.1
Falls of persons	31	17.8	31	17.4	26	14.4	88	16.6
Bumping against objects	3	1.7	3	1.7	5	2.8	11	2.1
Falling objects	6	3.5	22	12.4	13	7.2	41	7.7
Flying objects	2	1.1	18	10.1	11	6.1	31	5.8
Electricity	2	1.1	—	—	8	4.4	10	1.9
Drilling	10	5.8	3	1.7	6	3.3	19	3.6
Machinery	13	7.5	17	9.6	16	8.9	46	8.6
Stepping on objects	5	2.9	2	1.1	9	5.0	16	3.0
Burns	3	1.7	4	2.2	4	2.2	11	2.1
Other causes	4	2.3	5	2.8	4	2.2	13	2.4
Total	174	100.0	178	100.0	180	100.0	532	100.0
Cause not stated	38	—	7	—	9	—	54	—
Grand total	212	—	185	—	189	—	586	—

TABLE IX

NUMBER OF AND PERCENTAGE DISTRIBUTION OF DAYS OF DISABILITY FROM INJURIES AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1948-50, BY CAUSES

Causes	1948		1949		1950		Total	
	Days of disability	Per cent of total	Days of disability	Per cent of total	Days of disability	Per cent of total	Days of disability	Per cent of total
Falls and slides of rock	5,731	15.44	6,674	21.06	6,600	22.48	19,005	19.36
Handling materials	2,165	5.83	304	.96	759	2.59	3,228	3.29
Hand tools	2,328	6.27	290	.91	222	.76	2,840	2.89
Explosives	29	.08	6,061	19.12	17	.06	6,107	6.22
Haulage	18,836	50.74	8,315	26.23	3,762	12.81	30,913	31.49
Falls of persons	1,130	3.04	1,320	4.17	1,006	3.43	3,456	3.52
Bumping against objects	68	.18	32	.10	21	.07	121	.12
Falling objects	143	.39	610	1.93	6,147	20.94	6,900	7.03
Flying objects	12	.03	1,021	3.22	476	1.62	1,509	1.54
Electricity	3	.01	—	—	6,114	20.82	6,117	6.23
Drilling	218	.59	3,380	10.66	112	.38	3,710	3.78
Machinery	6,233	16.80	3,591	11.33	3,903	13.29	13,727	13.98
Stepping on objects	106	.28	14	.04	32	.11	152	.15
Burns	67	.18	67	.21	34	.11	168	.17
Other causes	53	.14	20	.06	156	.53	229	.23
Total	37,122	100.00	31,699	100.00	29,361	100.00	98,182	100.00
Cause not stated	473	—	478	—	128	—	1,079	—
Grand total	37,595	—	32,177	—	29,489	—	99,261	—

The injury record of the 6 underground mines in the 1950 contest was not favorable compared with the record in 1949. Owing to one fatality, the injury severity rate advanced to 8.900 days lost per 1,000 man-hours compared with the 1949 rate of 1.392. Injury frequency likewise was less favorable in 1950 for the underground mines and the rate advanced to 24.495 per 1,000,000 man-hours.

Crushed stone operations in 18 states were enrolled in the 1950 contest. Thirteen were in New York, 9 in Pennsylvania, 5 in Virginia, 4 in Ohio, 3 in Connecticut, 2 each in Iowa, Maryland, Missouri, and Texas, and 1 each in California, Illinois, Kentucky, Michigan, New Jersey, Oklahoma, Tennessee, West Virginia, and Wisconsin.

Causes of Injuries

Of the injuries with stated causes at the competing plants in 1950, injuries from falls of persons were 14.4 per cent of the total, handling materials 13.9 per cent, haulage 12.8 per cent, and falls and slides of rock 10.6 per cent. The severity of injuries by causes shows a different distribution from that on a frequency basis. Injuries from falls and slides of

rock had 22.5 per cent of the days of disability for all injuries at competing plants. Falling objects resulted in the next highest severity with 20.9 per cent of the total days lost from injuries and electrical accidents had 20.8 per cent of the days of disability. There was 1 fatality in each of these causes in 1950. Although machinery accidents represented only 8.9 per cent of the total number of injuries in 1950, these injuries had a time charge which was 13.3 per cent of the total days lost from all injuries owing largely to the 4 permanent partial injuries from this cause.

The Competition

The annual competition for the promotion of safety in the crushed stone industry is conducted by the Bureau of Mines under the same rules as the National Safety Competition and the same records are used in both contests. There are two additional qualifications for the crushed stone competition which are that the operation must have commercial production of crushed stone and that the company be a member of the Association.

TABLE X

AVERAGE DAYS OF DISABILITY PER TEMPORARY INJURY AT PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION

Year	Underground mines			Open quarries			Total		
	Number of temporary injuries	Number of days of disability	Average days of disability	Number of temporary injuries	Number of days of disability	Average days of disability	Number of temporary injuries	Number of days of disability	Average days of disability
1926	34	533	16	207	4,239	20	241	4,772	20
1927	14	68	5	458	7,186	16	472	7,254	15
1928	68	888	13	322	5,493	17	390	6,381	16
1929	30	617	21	286	5,533	19	316	6,150	19
1930	15	468	31	227	3,671	16	242	4,139	17
1931	4	147	37	198	3,540	18	202	3,687	18
1932	6	165	28	75	2,481	33	81	2,646	33
1933	11	349	32	67	2,893	43	78	3,242	42
1934	13	287	22	106	1,873	18	119	2,160	18
1935	3	249	83	77	3,015	39	80	3,264	41
1936	7	117	17	182	4,590	25	189	4,707	25
1937	3	91	30	136	4,461	33	139	4,552	33
1938	2	133	67	76	3,184	42	78	3,317	43
1939	7	457	65	51	1,678	33	58	2,135	37
1940	8	888	111	78	3,013	39	86	3,901	45
1941	15	169	11	98	2,266	23	113	2,435	22
1942	33	1,213	37	183	4,239	23	216	5,452	25
1943	45	1,123	25	134	3,862	29	179	4,985	28
1944	27	796	29	118	3,323	28	145	4,119	28
1945	22	755	34	135	3,505	26	157	4,260	27
1946	31	1,045	34	197	4,130	21	228	5,175	23
1947	29	1,588	55	197	4,990	25	226	6,578	29
1948	16	935	58	181	4,642	26	197	5,577	28
1949	17	467	27	153	3,345	22	170	3,812	22
1950	25	810	32	153	3,825	25	178	4,635	26
Total	485	14,358	30	4,095	94,977	23	4,580	109,335	24

TABLE XI

EMPLOYMENT AND INJURY DATA FOR CRUSHED STONE PLANTS ENROLLED IN THE NATIONAL CRUSHED STONE ASSOCIATION SAFETY COMPETITION, 1949 AND 1950, COVERING IDENTICAL PLANTS FOR BOTH YEARS AND PLANTS ENROLLED ONLY IN 1949 OR IN 1950 [1]

	No.	Man-hours worked	Number of injuries [2]					Days of disability [2]					Frequency rate [3]	Severity rate [3]
			F.	P. T.	P. P.	Temp.	Total	F.	P. T.	P. P.	Total	Total		
Plants enrolled in 1949 only	14	1,108,947	—	—	1	20	21	—	—	450	481	931	18.937	0.840
Identical plants enrolled both years, 1949	48	7,039,389	3	—	11	150	164	18,000	—	9,915	3,331	31,246	23.297	4.439
Identical plants enrolled both years, 1950	48	7,240,422	3	—	8	172	180	18,000	—	6,854	4,546	29,400	25.275	4.061
Plants enrolled in 1950 only	3	372,024	—	—	—	6	6	—	—	—	89	89	16.128	0.239

[1] As reports from mining companies are considered confidential by the Bureau of Mines, the identities of the operations to which this table relates are not revealed.

[2] F., fatal; P. T., permanent total disability; P. P., permanent partial disability; Temp., temporary disability.

[3] Frequency rate indicates the number of fatal, permanent, and other disabling injuries per million man-hours of exposure; severity rate indicates number of days of disability lost from injuries per thousand man-hours of exposure.

Some Safety Problems of the Crushed Stone Industry

By C. A. GUSTAFSON [1]

Chairman, Accident Prevention Committee
National Crushed Stone Association

THE rising costs of Compensation Insurance all over the country is making industry more and more Safety conscious. It is not lower costs alone that make a Safety program attractive, but by applying it we also get increased production and alleviate the pain and suffering of our employees. Peculiarly in our business we not only find the normal hazards that every manufacturing plant has but we also have special hazards foreign to other industries. In this article I shall endeavor to point out some of these hazards as well as to make some concrete suggestions towards making YOUR Safety program more effective.

> ELSEWHERE in this issue will be found the results of the NCSA Safety Contest for 1950. This competition for highest awards in Safety work, since the beginning of the contest 25 years ago, has become traditionally a vital part of our Association's activities, and has unquestionably stressed the importance of Safety work in our plans.
>
> This year NCSA has embarked upon another Safety Program designed to still further stimulate accident prevention work on the part of our members. This program of action has been developed by our Accident Prevention Committee of which Clarence A. Gustafson is Chairman. The accompanying article by Mr. Gustafson deals with some of the Safety problems peculiar to our Industry and which also shows how our producer members, by participating in this program, can strive to eliminate accidents to their employees. There is no Association activity which I, as your President, can more heartily endorse.
>
> Statistics covering membership participation to date in this program are indeed most gratifying. Detail reports on accidents, published and distributed to our members each month, have seemed to me interesting and particularly well done. I look for an even greater benefit from this new program as time goes on and membership participation increases.
>
> I certainly hope that our membership will give the cooperation necessary to make this program a complete success.
>
> J. R. CALLANAN, *President*
> *National Crushed Stone Association*

Major Trouble Spots

In the field of transportation, itself, we not only have the hazards dealing with over-the-road trucking, but most quarries also have a railroad problem either as a quarry haulage proposition or the loading of hopper cars for delivery, and in some cases both. In the plant we not only have the normal hazards of conveyor and drive belts, moving machinery, and housekeeping, but we are always faced, in addition, with the problems of flying stones, cleaning bins and hoppers, to say nothing of dust conditions. In the quarry proper, other hazards present themselves in the handling of explosives, the art of blasting, lifting and moving heavy stones, drillers clambering over loose stone on the muck pile, loose stone falling from the ledge, and high voltage problems where electric shovels operate. Even on the ledge where there are well drills, hazards crop up constantly concerning the operation of these machines.

Importance of Training New Employees

Every industry has the problem of training new employees. While possibly our turnover isn't as great as in a lot of other types of work, we still take on a certain amount of new help each year. Too often we neglect to train these men in Safety practices before an accident occurs. Even a laborer starting to work in the stripping gang should be FULLY informed as to the hazards he must encounter such as snakes, poison ivy, and falling of trees.

Whenever a new man is hired it will pay the superintendent to take fifteen minutes or so to explain the plant Safety program, special hazards, location of first aid kit, and the necessity for promptly reporting all accidents. The foreman in direct charge of the man should then go deeper into all known hazards and explain them in detail once the man is on the job.

Personal Safety has come a long way in the past fifteen years. Today Safety clothing, devices, and equipment are made to take care of practically every hazard. Strange as it may seem, a lot of men put up a battle when asked to wear the three primary articles (Safety shoes, goggles, and hard hats), even when furnished free of charge by the company. The complaints a superintendent gets about this equipment are almost unbelievable—"Shoes are hot in

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summer, cold in winter," "Shoes wear out socks," "Hard hats too heavy," "Goggles get dusty," "Goggles are too heavy," etc., etc., ad infinitum. Here is where the superintendents and foremen can set the example. How quick the men point out when the boss doesn't wear his hard hat! If the bosses wear these Safety articles continually, the men can have no arguments to present.

The Psychological Approach

We hear and read much of psychological warfare these days. In accident prevention work, we too can use this sort of technique to advantage in our war against accidents. The use of posters was possibly the first of this type of Safety work. They still do good work if the men see these posters displayed *neatly* every day. Sooner or later the messages sink into the subconscious mind.

Safety contests are another form of the psychological approach. All men respond to the spirit of competition and these contests are tools that can be used to advantage.

Still another device is the Accident Score Board showing number of days without a lost time accident. This is merely a cheaply made sign with hooks to hang new numbers on from day to day. Recently one of the optical companies has placed at the disposal of Safety men, glass eyes, free of charge. In each box with the "glassie" is a short paragraph entitled, "Would you swap one of yours for this?" Carry one with you and when a man isn't using his glasses when he should, give it to him saying, "You just won this." Upon seeing what it is he will immediately try to find someone else to give it to!

The Value of Safety Committees

Safety committees are also a useful adjunct to any Safety program. In our Industry usually the number of employees is relatively small and experience has shown an eight to twelve man committee is best; half of the number being permanent members made up of foremen or key men and the other half a rotating committee selected in some manner from month to month from the hourly wage hands. The superintendent or someone of executive calibre should sit in as chairman.

It is most important to confine the discussion entirely to Safety matters and not to allow it to become a springboard for petty gripes, union squabbles, etc., and when a suggestion is made and approved in the course of Safety Committee meetings, go all out to see that it is done. From time to time certain suggestions will be made that are impossible to do. The reasons why they are impossible or unfeasible should then be explained at once. But if worth while safety suggestions are not acted upon and the Safety committee is merely a lip service, the men will soon find it out with the result that the effectiveness of your own Safety Committee is made nil.

Management Can Make or Break the Safety Program

Here is where management can either make or break the Safety program. A Safety program isn't any better than what support management gives it. Too many times we find management saying, "We want a 100% Safety record and you boys go to it", but, management should follow through when it comes to spending a few dollars or letting a man take a minute or two to prepare his work safely. Every dollar spent in protective devices or men's time on Safety will pay for itself over and over again.

If management will back the program forcibly, the men quickly will know and understand the company means business and cooperation will be forthcoming. But, if management does not give its wholehearted support, the men soon realize it and they become careless and accidents mount. And it would seem most important for management to make the foremen understand that Safety is just as much a part of a supervisor's job as that of directing the men in their daily tasks.

Help the NCSA Accident Committee to Help You

The National Crushed Stone Association Accident Prevention Committee last year felt our members would benefit by reporting and receiving a review of all accidents occurring in plants of its producer members. The program started May 1, and to date 95 accidents have been reported, with the number of members participating continuing to increase. This method of keeping the members informed has paid off in several industry associations and our committee feels it will pay dividends in the National Crushed Stone Association. In our own company at South Bethlehem, I have found through these reports a few analogous conditions to accidents happening elsewhere. Better yet, when a number of twisted ankles were reported, the Safety committee was notified and they spread the word to the other employees—"Watch your step, don't step on small loose stones." To date we have no reports of this

type of accident. It is impossible to say that this warning is entirely responsible, but certainly it helps. I also found another condition similar to one reported in letting down hopper cars by gravity. The reported accident resulted in a permanent injury when a man was thrown off a car. I immediately checked our own operation and made sure the same type accident would not occur there.

The reports for the first three months show an appalling number of back injuries due to lifting, twisting, etc. These injuries are more often than not expensive and as soon as reported the insurance carrier usually sets up a reserve of several hundred dollars to offset the actual cost. It is vitally urgent that each member put on a drive to reduce this type of accident immediately. If in doubt as to the proper procedure to teach your men to lift properly ask your insurance carrier for help. Another suggestion is get Safety instruction cards on lifting from the National Safety Council. The cards are very cheap and can be placed in pay envelopes. Numbers 55, H102, and 434 are applicable to quarry work. No. 434 is for sacked material and possibly would be more for those producing bagged lime.

Your committee will be only too glad to help on any specific problem. We don't know it all but we feel we can at least give the members the benefit of our combined experiences. LET'S CRUSH OUT ACCIDENTS AS WE CRUSH STONE!

Annual Meeting of Highway Research Board

THE Thirty-first Annual Meeting of the Highway Research Board of the Division of Engineering and Industrial Research of the National Research Council will be held in Washington, D. C., at the building of the National Academy of Sciences, on January 15 through 18, 1952.

The program will provide a week of intensive activity in highway technology of all kinds and should yield information of practical value to crushed stone producers on a variety of subjects involving the use of crushed stone.

We are advised by Fred Burggraf, Director of the Highway Research Board, that all who may be interested are cordially invited to attend.

William H. Wallace

WE ANNOUNCE with sincere sorrow and a deep sense of loss the death of William H. Wallace, President of the Wallace Stone Company, which took place at his home in Bay Port, Michigan, on July 15, 1951. While not in good health for some time, his condition had apparently improved and he and Mrs. Wallace had made definite plans to attend the midyear meeting of the NCSA Board of Directors at Hot Springs, Virginia, on July 19. Announcement at the time of the meeting of his sudden passing greatly shocked his fellow Board members.

For many years, Bill, as he was familiarly known to his host of friends throughout the crushed stone industry, was a loyal, helpful, and enthusiastic participant in the affairs of the National Crushed Stone Association. He was first elected to the Board of Directors in 1940, and in 1946 was elected Regional Vice President for the Northern Region, which office he held at the time of his death. During his service on the Board and as Regional Vice President, he unselfishly devoted his talents to advancing the welfare of the Association.

In his home community Bill was ever alert to be helpful to others, actively participating in many civic enterprises. He was a veteran of World War I and a Reserve Officer in the U. S. Coast Guard, in which capacity he had many thrilling rescue experiences on storm tossed Lake Michigan.

We are sincerely saddened in the knowledge that Bill Wallace is no longer with us.

To his family and business associates we extend our deep and heartfelt sympathy.

Methods for the Determination of Soft Pieces in Aggregate[1]

By D. O. WOOLF
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Washington, D. C.

IN 1941, Subcommittee IX of the Society's Committee C-9 on Concrete and Concrete Aggregates requested that an investigation be made of methods of testing coarse aggregates to determine the content of soft pieces. It was hoped that the results of this investigation would direct attention toward the development of a new method of testing aggregates for soft pieces, or would identify existing methods suitable for this purpose.

This paper describes the methods employed and gives typical test values obtained. With each method of test are presented the conclusions obtained from the test data: whether the method appears to be useful, and the difficulties encountered in the performance of the test. Efforts have been made to develop a method suitable for use in the field. The detection of the amount of soft pieces in aggregates is properly a duty of the inspector in the field; consequently, the program of the investigation was planned with consideration of field use as a primary requisite. Any method which the inspector can use can also be performed in the laboratory. Some of the methods employed apparatus suitable for use in the laboratory only. In most of these cases, however, plans were prepared for the construction of equipment sufficiently portable to permit its installation at aggregate plants.

Classification of Materials

Prior to this investigation, information was solicited on materials which the various highway authorities classify as soft pieces. The state highway departments were requested to submit samples of the soft pieces encountered in their own states, and to furnish information relating to their particular conditions. The following information was requested:

1. The names of the different materials which may be classified as soft pieces.

2. The kinds which are found generally throughout the state or in large areas of the state.

3. The amount of soft pieces permitted in specifications for surface courses.

4. Method of test or identification used by laboratory operators or field inspectors (with descriptions if such are available).

5. The materials occurring naturally which are considered to be objectionable for surface courses but which are not included in the class of soft pieces.

Based on the information received, an alphabetical list of materials classed as "soft pieces" is given in Table I. The table also shows the number of states which classify the material as soft, and also the number of states which report the material to be widely distributed.

There are seeming incongruities in Table I. For example, granite is placed in the classification of soft pieces by two states, although to most persons the word "granite" conveys the impression of a hard and enduring stone and other apparent inconsistencies might be mentioned. However, some interpretation of these classifications is probably permissible. There is little doubt that the inclusion of granite in a classification of soft pieces is meant to refer to material of a granitic nature which has weathered to such an extent that the component crystals are soft or poorly bonded to each other. Similar interpretations can be made of a number of the materials included in the table, and in general, most of the materials mentioned can be placed in one or more of the following types:

1. Soft
2. Unsound
3. Light weight
4. Brittle
5. Friable
6. Highly absorbent

As indicated above, some materials may be both soft and friable, or soft and brittle, or different samples of the same material may be placed properly in

[1] A Report to Subcommittee IX on Specifications and Methods of Tests of Aggregates of A.S.T.M. Committee C-9 on Concrete and Concrete Aggregates.

TABLE I

LIST OF MATERIALS CLASSED AS "SOFT PIECES" AND NUMBER OF STATES GIVING THIS CLASSIFICATION OR HAVING MATERIAL WIDELY DISTRIBUTED

Material	Number of States		Material	Number of States	
	Classifying as soft	Wide distribution		Classifying as soft	Wide distribution
Basalt, disintegrated	1	1	Limestone, soft	3	1
Brownstone	1	1	Limestone, some varieties	1	1
Caliche, hard	1	0	Limestone, weathered	4	3
Chert	2	1	Limonite	3	2
Chert, chalky	1	0	Marble	1	1
Clay balls	2	1	Ochre	3	2
Clay, iron bearing	1	0	Quartz, sugar	1	1
Coal	2	1	Quartz, weathered	2	2
Concretion, calcareous	1	1	Rock, disintegrated	2	1
Conglomerate	1	0	Rock, weathered	2	2
Dolomite, weathered and porous	1	1	Rottenstone	1	1
Earth, diatomaceous	1	1	Sandstone	9	9
Feldspar	1	1	Sandstone, argillaceous	1	1
Felsite	1	0	Sandstone, friable	1	1
Floaters	1	1	Sandstone, friable arkosic	1	0
Gneiss	1	0	Sandstone, soft	5	4
Gneiss, micaceous	1	1	Schist, some	5	3
Gneiss, weathered	1	1	Schist, some	1	1
Granite	2	1	Schist, micaceous	1	0
Granite, decomposed	1	1	Schist, talc	1	0
Granite, disintegrated	4	3	Schist, weathered	2	2
Granite, micaceous	1	1	Scoria	1	1
Granite, weathered	3	3	Scoria, certain grades of	1	1
Gravel, cemented	2	1	Shale	11	7
Gravel, magnesia	1	1	Shale, clay	1	1
Iron clay balls	1	1	Shale, diatomaceous	1	1
Iron oxide	2	1	Shale, disintegrated	1	1
Limestone, argillaceous	2	1	Shell	2	1
Limestone, porous	1	1	Soapstone	1	0
Limestone, shelly	1	0	Volcanic rock, coarse	1	1

separate groups. Consequently, without reference to actual samples, a proper grouping of materials by name alone is probably not feasible. Certain materials, such as brownstone, micaceous granite, and limonite mentioned in Table I, are not identified definitely by the names given although the use of these terms may be justified on the basis of limited geographical usage. The desirability of applying more widely used, descriptive terms to describe materials of definite physical characteristics, is evident, as is the necessity for the establishment and use of a systematized glossary of terms relating to the materials under consideration.

Table II presents a list of materials classed as deleterious but not considered as soft pieces by the reporting authority. It is interesting to note that in this list of 37 entries, 17 are placed in the category of soft pieces by other states. This illustrates one of the difficulties encountered in attempting to coordinate requirements or tests for soft pieces in aggregate, for unless there can be some agreement as to what constitutes a soft piece, work along the proposed line may not be of suitable value.

TABLE II

LIST OF MATERIALS CLASSED AS DELETERIOUS OTHER THAN SOFT PIECES

Alkaline reactive	Mica
Amphibolite	Mud balls
Chert	Obsidian
Chert, opaline	Ochre
Chert, unsound	Pyrite in rock
Clay lumps	Quartzite
Coal	Sandstone, hard absorbent
Coated material	Sandstone, soft
Dolomite, some	Shale
Flint	Shale, hard
Glassy rock	Shale, opaline cherty
Gneiss, soft	Shale, soft
Granite	Shale, some
Granite, soft	Shell
Granite, some	Slate
Gravel, a quartz	Sulfates—sulfides, iron, in rock
Hydrophilic rock	Thin or elongated pieces
Limestone, argillaceous	Unsound pieces
Limestone, siliceous	

Table III presents a compilation of the various state specifications for soft pieces. Most specifications limit the content of soft pieces of aggregate to 5 per cent or less. In a few cases, limits for specific types of soft particles are given, but usually the

specifications fail to identify the materials covered by the requirement.

TABLE III

STATE SPECIFICATION REQUIREMENTS FOR SOFT PIECES

Item	Specification Limit, per cent	Number of Specifications
Soft pieces	2	2
	3	3
	5	4
	10	1
	Free from excess	1
Soft pieces, bituminous aggregate	1	2
Soft pieces, concrete aggregate	2	2
	3	1
Soft piece: Concrete aggregate	6	
Cover material	7	1
Oil mix material	12	
Stabilized material	20	
Clay lumps	0.5	
Shale	2.0	1
Specific gravity less than 1.95	2.0	
Total shale, coal, clay lumps, and soft fragments	5	1
If loss in Na_2SO_4 test is less than 2 per cent, soft shale may not exceed	10	1
If loss is 2.0 per cent or greater, soft shale limited to	6	

Table IV lists the methods of test for determining the content of soft pieces of aggregates. The methods most commonly used are visual inspection, the Los Angeles abrasion test, the scratch test, and a test using a hand hammer or compression machine. These and the other tests listed are of two types: a test in which the individual particles are examined separately; and a test in which the effect of soft pieces on a characteristic of the entire material is determined. It should be noted that, with the exception of the requirement involving the use of the sodium sulfate test, all of the specification requirements shown in Table III necessitate the use of the first type of test and, in the one exception, this type of test is used in part. Consequently, it appears that determinations of the content of soft pieces should be based on actual count or weight of particles rather than on the use of an indirect method involving some characteristic pertaining to the whole sample.

TABLE IV

METHODS OF TEST FOR IDENTIFYING SOFT PIECES AND NUMBER OF STATES USING METHOD

Method	Number of States
Los Angeles abrasion test	10
Breakage test under roller	1
Visual inspection	14
Scratch test	4
Hand hammer or compression test	4
Douglas stonemeter	2
Specific gravity	2
Solubility in acid	1
Sulfate soundness test	2
Absorption test	1
Flotation by heavy liquid	1
Gravel impact test	1
Deval abrasion test	1

As listed in Table IV, several states use certain methods of test, the Los Angeles abrasion test for example, for determining the presence of soft pieces in aggregate. However, these states fail to include numerical values in their reported requirements for soft pieces which are applicable to these methods. Although the reporting authorities may consider the methods mentioned to be suitable for use, it is probable that lack of sufficient test data has so far prevented the establishment of specification requirements.

Eighty-four samples of aggregates were submitted by the states in response to our request for typical samples of material composed of soft pieces. In a number of cases the samples were confined, as requested, to a given type of material. However, many samples were found to be composed of a number of kinds of material differing as greatly as limestone and gneiss. It is possible that our request for samples composed wholly of soft pieces was misunderstood, and that some samples were submitted which contained a small amount of soft pieces naturally occurring in these materials.

From the varieties of materials submitted as soft pieces, it is apparent that there is no concordance of opinion as to the kind of material which should be thus described. It is further apparent that the term, "soft pieces," is used as a catch-all description of a number of different types of possibly undesirable material in aggregates. Before spending much time in testing materials, some rational conception must be had of the type of material to be identified by the test procedure. Choice must be made between the application of the term, "soft pieces," to pieces of aggregate which are actually soft, or to pieces of a wide variety of characteristics. Although these latter may be undesirable for use in construction, this is their only common feature. As shown in the samples submitted, these pieces may be hard or soft, tough or brittle, sound or unsound; in fact, they include the whole gamut of physical properties of aggregates. If our tests are to identify soft pieces, the only question to be considered is whether the

piece under test is hard or soft. During the course of this investigation, tests foreign to a strict hard-or-soft determination were made, whereby it was hoped that some correlation between the hardness of the particle and some other characteristic of interest could be established. As a general rule, the results were rather disappointing. In some cases with selected samples we did find definite correlations between the hardness of a material and some other characteristic, but when a wider variety of samples was considered, the agreement between the two characteristics appeared to be largely a matter of chance.

Methods of Test

The tests made in this investigation may be grouped in the following classifications:

Visual inspection
Scratch hardness
Specific gravity and absorption
Resistance to impact
Resistance to abrasion
Resistance to static loads
Soundness

In some cases, the tests were made on the material as received, that is, without preliminary separation into individual sizes. In most tests, however, the size of the piece affected the test result to a marked extent, and it was necessary to sieve the test sample into separate sizes. The sizes generally used were 2 to 1 1/2, 1 1/2 to 1, 1 to 3/4, and 3/4 to 1/2 in. Pieces smaller than 1/2 in. were found to be difficult to test by some methods, and it was deemed sufficient, for the present at least, to study methods of testing the larger pieces only.

In the first series of tests made on the 84 samples submitted by the state highway departments, the samples were separated into three groups with respect to hardness of the material: soft, hard, and borderline. This was done by a combination of visual inspection and the use of a scratch test employing a steel knife. It was realized that these methods are not dependable for separating any and all materials into hard and soft classifications; however, they can be used to separate unquestionably soft material from unquestionably hard material. The materials which were found to be neither hard nor soft were classified as borderline materials and excluded from further tests.

Visual inspection of aggregates for the presence of soft pieces is associated with what might be called the luster or appearance by reflected light, and the degree of bonding. Pieces of aggregate with a glassy or stony luster are usually classed as hard; those with a dull or earthy appearance are classed as soft. Compact materials are usually placed in the hard classification, but those which have a loose or friable texture are considered as soft.

FIGURE 1
Toughness Test (2 1/2-in. Ball) for Gravel

Specific Gravity and Absorption

Tests for bulk specific gravity were made on saturated and surface-dry samples using the mason jar pycnometer.[2] This determination does not appear to have any significance in differentiating between hard and soft pieces. Seven samples of hard materials had bulk specific gravities varying from 1.62 to 2.55; five samples of soft materials varied from 1.48 to 2.57; eight samples classed as borderline materials

[2] Described in "Principles of Highway Construction as Applied to Airports, Flight Strips, and Other Landing Areas for Aircraft," *Public Roads Administration*, June 1943, p. 297.

varied from 2.11 to 2.59. With so much overlapping of test values, use of the test for specific gravity to identify hard and soft pieces does not appear feasible.

The absorption test was made by immersing oven-dried samples in water for a period of 24 hr. The samples were then surface-dried with a towel and weighed, and the absorption expressed as a percentage of the dry weight. A summary of the results obtained is given in Table V. In this table, as in others to follow, each size of each material tested is treated as an individual sample. This permits comparisons between the two types of material, hard and soft, for each size of piece. Although the average values for the two types of material differ markedly, there is some overlapping in the test values. In the 1 to 3/4-in. size, for example, one sample of soft material has an absorption of only 3.2 per cent, whereas a sample of hard material has a quite high absorption of 11.3 per cent. Because of this overlapping, it is not possible to set a value separating hard from soft material and this method is of little use for the identification of soft particles.

TABLE V

USE OF THE ABSORPTION TEST FOR THE IDENTIFICATION OF HARD AND SOFT MATERIALS

Item	Size of piece, in.			
	2 to 1 1/2	1 1/2 to 1	1 to 3/4	3/4 to 1/2
Soft Material				
Number of samples	4	30	31	20
Absorption, per cent				
Minimum	2.6	2.6	3.2	4.3
Maximum	23.4	30.1	29.0	30.9
Average	11.5	12.8	14.4	18.2
Hard Material				
Number of samples	6	22	22	10
Absorption, per cent				
Minimum	1.4	0.5	0.6	1.0
Maximum	11.1	11.3	11.3	11.0
Average	4.7	2.7	3.0	3.3

Impact Tests

Several different types of impact tests were used. The one believed to have the most promise is the test for the toughness of gravel.[3] As shown in Figure 1, the apparatus used in this consists essentially of a 2 1/2-in. steel ball mounted on a steel block to serve as an anvil, and another steel ball of the same size which can be lifted to a maximum height of 7 in. and allowed to fall on the specimen under test. During the course of this investigation, certain improvements in the original apparatus were made so that the ball could be dropped the exact distance desired with but one measurement of the thickness of the specimen under test.

[3] Method T-6, American Assn. of State Highway Officials Book of Standards, 1938, p. 152. This method has been withdrawn by the Association.

In making this test, the specimen was held on the anvil in its most stable position, usually with the least dimension vertical, and the movable ball dropped on the specimen from a height of 1 in. The height of fall was increased 1 in. after each blow until the specimen failed or until it withstood a drop of 7 in. Under normal conditions, a test sample containing 50 to 100 pieces of the same sieve size was used. An empirical value for each sample was obtained by multiplying the number of pieces which failed at each successive height of drop, by the square of the drop, in inches, and dividing the sum of these values by the total number of pieces tested. For the purpose of this computation, pieces which did not fail at a drop of 7 in. were assumed to fail at a drop of 10 in. This value, called the toughness factor, can vary from a minimum of 1 to a maximum of 100.

The results of these tests are shown in Table VI. Although higher toughness factors were found for the hard materials than the soft, there is a considerable amount of overlapping of the two sets of values.

TABLE VI

USE OF THE TOUGHNESS TEST (2 1/2-IN. BALL) FOR THE IDENTIFICATION OF HARD AND SOFT MATERIALS

Item	Size of piece, in.			
	2 to 1 1/2	1 1/2 to 1	1 to 3/4	3/4 to 1/2
Soft Material				
Number of samples	3	28	29	20
Toughness factor				
Minimum	18.0	2.7	2.0	1.0
Maximum	59.0	46.2	16.9	5.7
Average	41.6	20.5	7.9	2.5
Hard Material				
Number of samples	7	23	23	10
Toughness factor				
Minimum	5.0	4.5	2.9	1.1
Maximum	79.0	67.2	32.3	10.3
Average	42.3	29.8	11.4	3.8

It is apparent that the toughness test for gravel does not separate hard from soft material. It appears that the falling ball is much too heavy to separate soft pieces from hard but brittle pieces. Furthermore, when the brittle piece fails, the fracture is apparent, but many pieces of soft material may fail without the break being seen from above as the operator would normally view the specimen. This results in the soft piece receiving a higher rating than it should have, thereby decreasing the value of the test.

FIGURE 2
Rotary Soft Stone Machine

In an attempt to correct these difficulties, another toughness apparatus was made using a steel ball of 1 7/8-in. diameter. For certain sizes of particle, the 1 7/8-in. ball was found to furnish more indicative test results than the 2 1/2-in. ball, but the conclusion was reached that to test aggregate of a complete range in size from 2 or 2 1/2 to 3/8-in., at least three toughness testers of different sizes should be used, and each size used to test material of a definite and narrow range in sieve sizes. As time to develop these tests and correlate the test results of each was not available, further consideration of the use of this type of apparatus was deferred.

Rotary Soft Stone Machine:

Another type of impact test tried involves the use of the rotary soft stone machine shown in Figure 2. This machine consists essentially of a cast iron disk revolving in a horizontal plane inside a vertical steel drum made of 3/8-in. plate. The disk is 29 in. in diameter and the drum has an inside diameter of 33 1/4 in. Ribs on the upper surface of the disk form pockets to catch the material fed on the disk through a sheet metal cone, and to throw these pieces against the steel drum. Another cone below the disk serves to collect the sample and lead it to a pan in which the tested material can be inspected. The disk is powered by a variable speed motor and can be operated at speeds from 110 to 200 rpm. In these tests, the fastest speed was used. The test was conducted on individual sizes of aggregate. The weight of the test sample was determined and the pieces passed singly through the machine. After all pieces had been tested, the sample was sieved on the original retaining sieve, and the weight of material passing this sieve expressed as a percentage of the original weight of the sample.

The results obtained with the rotary machine are given in Table VII. These results indicate the same

TABLE VII
USE OF THE ROTARY SOFT STONE MACHINE FOR THE IDENTIFICATION OF HARD AND SOFT MATERIALS

Item	Size of piece, in.			
	2 to 1 1/2	1 1/2 to 1	1 to 3/4	3/4 to 1/2
SOFT MATERIAL				
Number of samples	3	25	28	18
Loss, per cent				
Minimum	13.5	2.5	2.5	1.4
Maximum	22.0	29.9	21.4	20.8
Average	19.0	11.2	10.4	9.6
HARD MATERIAL				
Number of samples	5	19	21	9
Loss, per cent				
Minimum	1.0	2.0	2.5	1.4
Maximum	24.0	19.5	32.0	34.2
Average	15.9	10.3	9.9	11.6

conditions as were found for the falling ball apparatus. Hard but brittle material as well as soft material is readily broken in the rotary machine, and it does not appear possible to separate truly soft pieces from others with this type of test.

FIGURE 3
Hammers and Scribes Used in Soft Piece Test
Left to right: 2-lb. stone mason's hammer, 1-lb. tinner's hammer, 8-oz. tinner's hammer, 2-oz. tile setter's hammer, brass scratch pencil, knife, and rubber mallet

Hand Hammer Tests:

Several other types of impact tests were tried. In former years, a hammer test was occasionally used to identify soft pieces. Although the application of a hand hammer involves a number of indefinite conditions, it was believed desirable to include this test in the investigation. The hammers used varied from a 2-oz. tile setter's hammer to a stone mason's hammer with a 2-lb. head as shown in Figure 3. Several different types of technique were used. In one, the hammer was allowed to drop without bending of the wrist; in another, the hammer was swung by movement of the wrist only; in a third, the end of the hammer handle was placed on the table and the hammer head allowed to fall through an arc of about 8 in. The tile setter's hammer has one flat and one sharply beveled end. With this hammer, one method included a free swing of the arm, with the flat face striking the piece under test. In another application of the same small hammer, the beveled end was used to peck at the test specimen to determine whether the material could be flecked away or cut by light taps. Consideration was also given to the type of failure of a specimen under blows of a reasonably heavy hammer. It was thought that if the material were soft, it would crush under the hammer, producing a large amount of powder with relatively few large fragments. Hard material, on the other hand, would break to sharp-edged fragments with relatively little powdering. Of all these tests, none gave satisfactory results, and this type of test was discontinued.

Consideration was then given to an impact test using as the striker an article which would deform

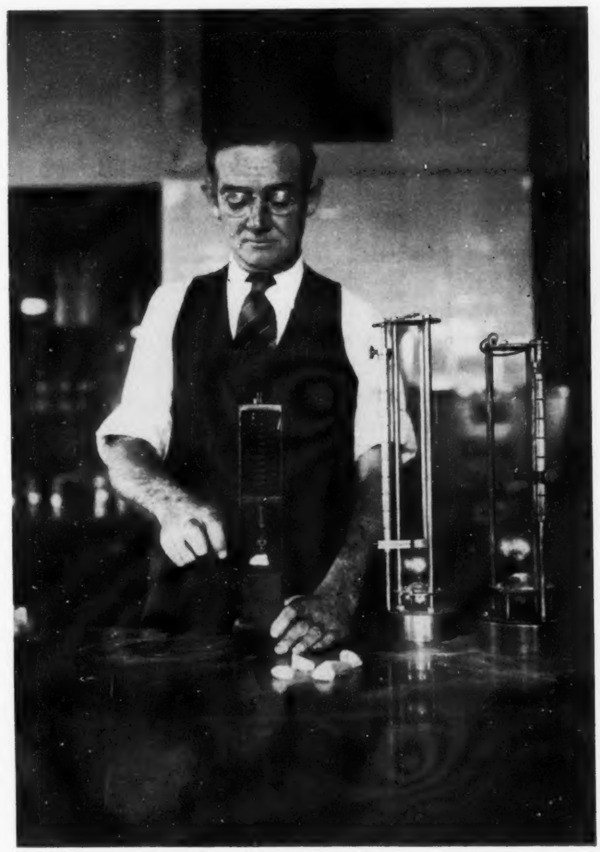

FIGURE 4
Douglass Stone Meter in Use
To the Right Are the Toughness Machines With the 1 7/8-in. and 2 1/2-in. Balls

around the piece under test but still transmit stress to the piece. The articles considered for this application were a device known in some circles as a blackjack, and a mallet with a rubber head such as is used in removing dents from automobile bodies. A blackjack having a leather case filled with lead shot was tried, but after a few tests the leather broke and further consideration of this was discontinued.

For a few very soft materials, the rubber mallet gave satisfactory results, but moderately soft materials of 1-in. size or larger could not be crushed with the mallet. This test was also discontinued.

Compression Tests

The suitability of a compression test to identify soft pieces was tried. A small apparatus[4] for such a test has been used, but the maximum load specified is only 75 lb. and this load will crush only the weakest specimens. This apparatus is shown in Figure 4. The use of an hydraulic compression testing machine was then proposed. In the method considered, an attempt was made to apply load to the particle through 1/2 in. steel balls. For pieces of irregular shape, this was very difficult to perform, and flat-faced steel cylinders of 1/2 in. diameter were substituted for the balls. The pieces under test were ground on a lap to secure bearing faces, and were tested with the least dimension in a vertical position. Load was applied at a slow but predetermined rate and failure determined to the nearest 10 lb. Each sample tested contained from 20 to 100 pieces.

The results obtained are given in Table VIII. It will be observed that no well-defined separation between hard and soft materials is obtained. Study of the pieces under load revealed one interesting feature. In testing a shale which occurs in rather thin pieces, it was noticed that the portion of the piece not in contact with the loading cylinders fell away at a relatively low load, but the material between the loading cylinders became more compact as the loading continued. In one case, this material was loaded to 35,000 lb. or almost 180,000 psi. It is apparent that this type of loading is unsuitable for thin specimens of soft material and that the test does not separate hard from soft material.

TABLE VIII

USE OF THE COMPRESSION MACHINE FOR IDENTIFICATION OF HARD AND SOFT MATERIALS. LOAD APPLIED THROUGH FLAT FACES OF 1/2-IN. DIAMETER

Item	Size of piece, in.			
	2 to 1 1/2	1 1/2 to 1	1 to 3/4	3/4 to 1/2
SOFT MATERIAL				
Number of samples	4	9	20	8
Compressive strength, lb.				
Minimum	1130	540	120	120
Maximum	2910	2970	2770	3530
Average	1840	1270	860	1010
HARD MATERIAL				
Number of samples	5	10	13	3
'Compressive strength, lb.				
Minimum	500	860	690	480
Maximum	3460	2950	3250	1290
Average	1890	1830	1750	860

[4] Douglass stone meter described in Method T-8, American Assn. of State Highway Officials Book of Standards, 1938, p. 154. This method has been withdrawn by the Association.

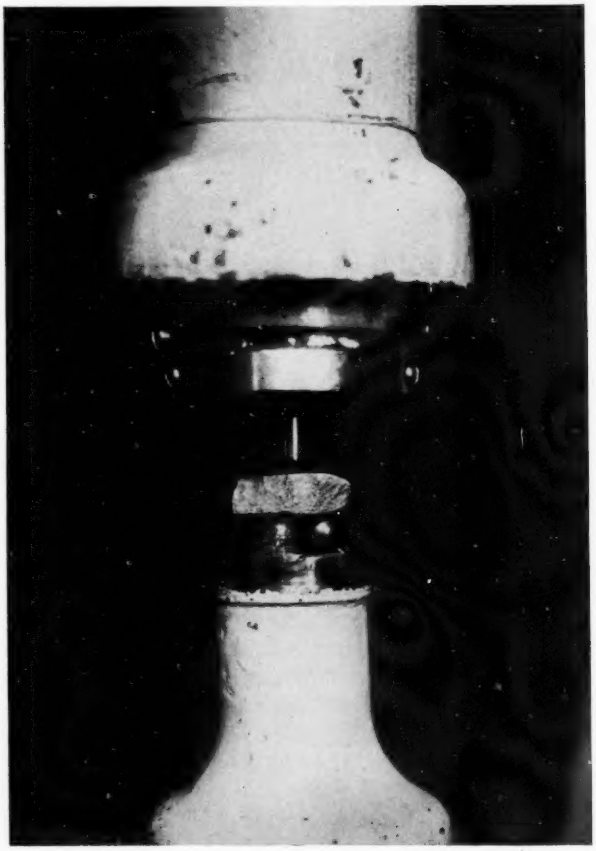

FIGURE 5
Compression Test for Soft Pieces
Three Point Support and Single Point Load

A subsequent restudy of the data indicated that possibly a fair trial had not been given to the compression test. The labor of grinding faces on 50 to 100 pieces of each size in each sample tested was considered objectionable, and some means of testing pieces of any shape without preliminary grinding was sought. Trials were made of a number of different types of loading devices. After considerable

work, a loading device consisting of a single point upper contact and a three point lower support was adopted. As shown in Figure 5, the upper contact consists of a short steel rod of 1/2-in. diameter, with a hemispherical end, which is fastened to the spherical bearing block of an hydraulic cube-testing machine. The lower bearing consists of three 1/2-in. diameter steel balls grouped together so that their surfaces are in contact, and welded to a small steel base. With this loading and support arrangement, most pieces of both regular and irregular shape can be placed in a stable position for the test.

To obtain values for use in identifying pieces of hard, sound aggregate, several hundred pieces of each size of three different materials were tested and the breaking load of each piece determined. From the data obtained, the following loads were selected as indicating hard materials:

Size of Piece, in.	Load, lb.
3/8 to 1/2	200
1/2 to 3/4	350
3/4 to 1	500
1 to 1 1/2	750
1 1/2 to 2	1100
2 to 2 1/2	1500

Based upon these tentative values for hard material, tests were carried out in conjunction with certain other tests, as described below under Tests of Commercial Gravels.

Freezing-and-Thawing Test

The freezing-and-thawing test was used to determine whether any relationship could be established between the results of this test and the hardness of the materials considered. The samples were immersed in water for 24 hr. prior to freezing, frozen at about 15 F. in water and thawed at about 80 F. A 24-hr. cycle was used. After ten cycles of the test, the samples were examined. With only a few exceptions, this short test failed to differentiate between hard and soft materials. The test was then resumed for another ten cycles. After the twentieth cycle, the samples were dried, sieved on a sieve with openings having linear dimensions one-half the size of those in the original retaining sieve, and the material passing the sieve expressed as a percentage of the weight of the original sample. The half-size sieves were used rather than the original sieve to prevent the inclusion in the loss of those pieces which might pass the original retaining sieve due only to minor flaking or chipping. The results of these tests are given in Table IX.

TABLE IX

USE OF FREEZING AND THAWING (20 CYCLES) FOR IDENTIFICATION OF HARD AND SOFT MATERIAL

Item	Size of piece, in.			
	2 to 1 1/2	1 1/2 to 1	1 to 3/4	3/4 to 1/2
Soft Material				
Number of Samples	1	12	21	11
Loss passing ½-size sieve, per cent				
Minimum		3.1	5.0	9.4
Maximum		92.8	93.0	92.2
Average	9.2	26.1	42.5	51.5
Hard Material				
Number of samples	4	11	14	3
Loss passing ½-size sieve, per cent				
Minimum	2.7	0.6	0.4	5.4
Maximum	31.6	18.2	51.4	25.3
Average	11.8	5.0	11.4	13.1

Tests of Commercial Gravels

For further tests, the National Sand and Gravel Assn. was requested to furnish samples of commercially produced gravels which would contain some soft material, since the material supplied by the states was almost exhausted. To the samples received from the Association were added a number of gravels which had been submitted to the laboratory for routine tests. These samples were tested for soft piece content using the compression test described above, the 20-cycle freezing-and-thawing test, and the Los Angeles abrasion test. In the last test, determinations of the percentage of wear were made at 100 and 500 revolutions and a ratio of the losses used as an expression of the amount of soft material in the sample.

The results of these tests are given in Table X. Inspection of the results discloses immediately that there is little agreement between the indications of the three methods of test. For some few samples, all three methods show the presence of appreciable amounts of soft material. In most cases, however, the three methods give different results. One reason for non-uniformity among the three methods is the unit of failure on which the test result depends. In the compression test, the pieces of the sample are tested separately, and the whole piece is discarded if it fails to meet the conditions of the test. In the Los Angeles abrasion and freezing-and-thawing tests,

it is entirely possible that only a portion of a given particle may be included in the loss. Consequently, it is doubtful that any satisfactory agreement among different methods of test can be established unless the unit of failure is the same in each case.

TABLE X

SOFT PIECE TESTS ON COMMERCIALLY PRODUCED GRAVELS

Sample	Los Angeles abrasion test			Compression Test, per cent soft by weight	Freezing-and-Thawing 20 Cycles, Loss, per cent
	Loss at 100 Revolutions, per cent	Loss at 500 Revolutions, per cent	Ratio of Losses, 100/500, per cent		
No. 67464	6.0	28.1	21.4	....	27.4
No. 67621	4.9	24.2	20.2	....	10.4
No. 67622	4.4	22.7	19.4	....	10.3
No. 67628	8.1	32.6	24.8	....	9.1
No. 67629	5.4	27.3	19.8	....	9.3
No. 67680	4.2	23.4	17.9	....	6.8
No. 67696	4.6	23.8	19.3	....	7.5
No. 67757	5.6	23.6	23.7	12.1	4.2
No. 67858	7.3	26.4	27.7	....	11.0
No. 67909	5.6	23.3	24.0	....	17.0
No. 67910	4.2	25.0	16.8	....	17.2
No. 67954	6.1	27.8	21.9	....	20.4
No. 68516	5.6	26.5	21.1	15.6	11.2
No. 68768	7.6	30.7	24.8	24.5	19.7
No. 68769	5.4	26.3	20.5	19.5	6.5
No. 68770	5.7	27.1	21.0	21.3	5.7
No. 68771	4.1	21.3	19.2	14.4	7.6
No. 68772	6.5	29.0	22.4	26.2	8.4
No. 68773	5.3	26.6	19.9	23.7	3.8
No. 68774	8.5	32.9	25.8	33.1	12.7
No. 68775	6.8	30.8	22.1	18.8	8.9
No. 68776	6.4	31.8	20.1	38.9	21.3
No. 68777	7.4	32.4	22.8	29.8	29.2
No. 68778	6.8	29.6	23.0	14.0	4.1
No. 68779	5.8	25.5	22.8	23.7	2.4
No. 68780	6.6	30.3	21.8	17.6	9.5

Consideration of the values obtained in the compression test shown in Table X indicates that the limits set for the identification of hard pieces are probably too severe. A review of the individual test results for each sample shows a very high percentage of failures for pieces in the smaller sizes and also an excessive percentage of failures for pieces which tend toward a flat shape. In this test, the point of application of the load is normally above a point equidistant from the point of support of each of the three balls in the lower bearing. With thin or flat pieces, this could result in flexure of the piece under test, and the failure would be by bending instead of by compression.

Review of Methods of Test

Late in 1946 several new methods of testing aggregates for content of soft pieces were suggested. These included a scratch test using a scribe of yellow brass, and two abrasion tests. In one of these abrasion tests, the sample was placed in a canvas bag with a charge of steel balls and the bag dropped on or swung against an anvil a given number of times. In the other test, the sample alone was placed in a bag and subjected to blows delivered by a rubber-headed mallet, freely swung as shown in Figure 6. In trying these methods, it was considered desirable to include in the program of tests some of the methods which had previously been used.

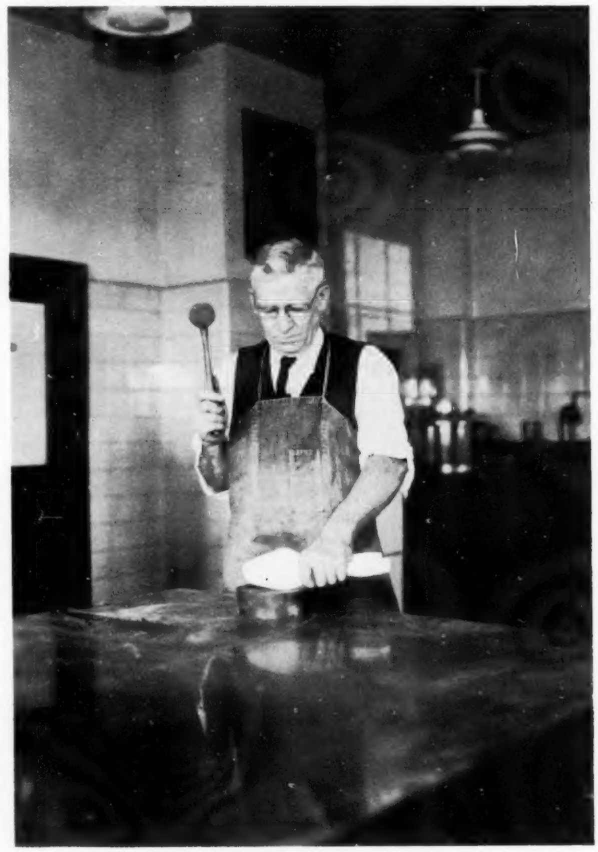

FIGURE 6
Bag and Mallet Test for Soft Pieces

The material used in these tests consisted of quartz gravel of a reasonably uniform hardness to which was added definite quantities of soft stone or gravel obtained from the remnants of the samples received in 1941. Objection was made that the personnel would be influenced by the color of the different pieces and would unconsciously classify pieces on this basis. Consideration was given to the possibil-

ity of dyeing all the material to be used to a uniform color, or fitting the operators with colored glasses. Both suggestions were rejected and the difficulty overcome in part by the use of some soft material of nearly the same color as the base gravel. Furthermore, most of the tests made have definite end points, and the operator is not required to decide whether the material does or does not meet the conditions of the test.

Several changes in the test procedure as previously used were thought to be desirable. A brief description of each method used is given below:

Method 1:

Steel scratch test.—Each piece was scratched with a sharp knife blade. The weight of the pieces identified as soft was reported as a percentage of the original weight of the sample.

Method 2:

Brass scratch test.—Each piece was scratched with a pointed scribe prepared from 1/4-in. diameter yellow brass rod. The results were reported as in Method 1.

Method 3:

Light hammer test.—The test piece was placed on an anvil in its most natural position of repose, held firmly with the fingers, and struck at the center of the upper face with the flat end of the tile setter's hammer. The hammer was swung through an arc of about 6 in. using a natural movement of the wrist only. Softness was recognized by crushing or crumbling of the piece under test. A clean fracturing or splintering of the piece, that is, breaking into smaller but solid fragments without considerable powdering, was not considered indicative of softness. More than one blow was permitted if necessary to classify the piece properly. The results were reported as in Method 1.

Method 4:

Rubber mallet test.—The method followed the procedure given in Method 3.

Method 5:

Toughness test for gravel.—The 2 1/2-in. ball was dropped as follows:

Size of piece, in.	Height of fall, in.
1 1/2 to 1	3
1 to 3/4	2
3/4 to 1/2	1

The test piece was held on the anvil and adjusted under light tapping of the free ball to a secure bearing. The free ball was then raised to the height indicated for the size of aggregate under test and allowed to fall on the piece. Softness of the piece was shown by crushing, powdering, or crumbling. Each sample was reported as in Method 1.

Method 6:

Toughness test for gravel.—The procedure given in Method 5 was repeated using the apparatus containing the 1 7/8-in. ball, except that the heights of fall were:

Size of piece, in.	Height of fall, in.
1 1/2 to 1	5
1 to 3/4	3
3/4 to 1/2	1

Method 7:

Rotary soft piece test.—The machine was operated at its slowest speed (about 110 rpm.). The pieces of the test sample were fed separately into the machine and all debris caught. The material passing the original retaining sieve was determined, and expressed as a percentage, by weight, of the original sample.

Method 8:

Douglass stone meter test.—The following loads were used:

Size of piece, in.	Applied load, lb.
1 1/2 to 1	125 (Maximum loading of spring)
1 to 3/4	75
3/4 to 1/2	60

The results were reported as in Method 1.

Method 9:

Compression test.—The tests were made in the hydraulic testing machine, using the following loads:

Size of piece, in.	Applied load, lb.
1 1/2 to 1	500
1 to 3/4	350
3/4 to 1/2	200

The piece tested was placed in its most stable position on the three point support, and load applied without shock through a single point contact on the upper surface of the specimen. Breakage of the specimen at a load below those indicated constituted failure. The results were reported as in Method 1.

Method 10:

Bag abrasion method.—A 1000-g. sample was placed in a 10 by 14-in. canvas bag with an abrasive charge of five 1 7/8-in. diameter cast iron or steel balls. The neck of the bag was fastened securely to prevent loss of the sample. The bag was swung 100 times through a distance of 12 in. against an anvil. The sample was then removed from the bag and sieved on a No. 4 sieve. The material passing this sieve was expressed as a percentage of the original weight of the sample.

Method 11:

Bag and mallet method.—A 1000-g. sample was placed in a 6 by 9-in. canvas bag and the neck fastened securely to confine the sample in the least space. The bag was then placed on an anvil and struck 100 times with a rubber-headed mallet. The blows were distributed over the side of the bag, and after each tenth blow the bag was turned over to expose the lower side. The results were determined as in Method 10.

Method 12:

Los Angeles abrasion test.—Samples weighing 5000 g. of each size of material were tested with an abrasive charge of twelve steel balls weighing 5000 g. The percentage of wear was determined at 100 and 500 revolutions.

Discussion of Test Results and Methods of Test

The results obtained in these tests are given in Table XI. The values shown at the top of the table are the percentages by weight of soft material which were added to the quartz gravel. The values given in the rest of the table, except for those of the Los Angeles abrasion tests, are the percentages by weight of soft material found by the test method indicated. The values given for the Los Angeles tests are the losses in percentages by weight obtained in the tests. The ratio of the losses at 100 and 500 revolutions has been thought to have some relation to the amount of soft material in the sample. A comparison between these values and the amounts of soft material actually added to the base gravel indicates that this test as made on individual sizes of aggregate, does not furnish test results which are indicative of the amount of soft material in the sample.

The most favorable results obtained in this series of tests are those furnished by the brass scribe, the rotary soft piece machine, and the bag and mallet test. In previous work, when the rotary machine was operated at a speed of 200 rpm., it had not given very significant results. Although much better results are obtained when the machine is operated at a slower speed, further consideration of this type of testing equipment was discontinued as the machine is not suitable for field use.

TABLE XI

RESULTS OF TESTS FOR SOFT PIECES USING PREPARED SAMPLES

Method	Soft Pieces, per cent			
	Size of Piece, in.			
	1-1/2 to 1	1 to 3/4	3/4 to 1/2	Average
Soft pieces placed in material	4.8	16.2	10.4	10.5
Scratch Hardness Methods				
By steel scribe	17.6	18.2	14.9	16.9
By brass scribe	4.8	16.3	10.6	10.5
Impact Methods				
2-oz. hammer	11.3	18.8	17.9	16.0
Rubber mallet	1.4	10.1	12.6	8.0
Rotary machine	14.6	10.6	10.9	12.0
Toughness 2-1/2 in. ball	10.2	34.1	21.1	21.8
Toughness 1-7/8 in. ball	20.1	22.0	10.2	17.4
Compression Method				
Douglass machine	8.5	4.8	0.6	4.6
Three point support	4.2	16.9	21.0	14.0
Abrasion Method				
Bag abrasion	6.7	18.0	14.0	12.9
Bag and mallet	6.4	11.7	11.7	9.9
Los Angeles machine				
Loss at 100 revolutions	5.1	11.9	14.8	......
Loss at 500 revolutions	22.5	40.3	45.3	......
Ratio 100/500	22.7	29.5	32.7	......

Bag and Mallet Test:

Some question developed regarding the size of sample which would be most desirable in the bag and mallet method, and also how many tests should be made to obtain a test value representative of a given material. From a practical consideration, a sample of the size used appears to be about as large as is desired for readiness of handling. Should the

material to be tested have a maximum size greater than 1 1/2 in., the size of the test sample must be increased and a larger bag used. Considerable development work along this and other lines remains to be done before this method can be adopted for use. To determine the other feature of particular interest here, that is, the number of 1000-g. samples which should be tested for a material with a maximum size of 1 1/2 in., another series of tests was made.

TABLE XII

BAG AND MALLET TESTS ON PREPARED SAMPLES OF QUARTZ GRAVEL CONTAINING SOFT SANDSTONE

Sample	0 per cent Soft Stone		4 per cent Soft Stone		8 per cent Soft Stone		12 per cent of Soft Stone	
	Loss, per cent	Cumulative Average Loss, per cent	Loss, per cent	Cumulative Average Loss, per cent	Loss, per cent	Cumulative Average Loss, per cent	Loss, per cent	Cumulative Average Loss, per cent
No. 1	4.4	4.4	6.2	6.2	12.5	12.5	9.7	9.7
No. 2	3.7	4.0	6.2	6.2	9.9	11.2	11.2	10.4
No. 3	5.9	4.7	6.3	6.2	8.7	10.4	12.3	11.1
No. 4	4.3	4.6	7.4	6.5	10.6	10.4	10.7	11.0
No. 5	3.7	4.4	5.8	6.4	8.2	10.0	13.1	11.4
No. 6	3.9	4.3	7.0	6.5	9.0	9.8	12.4	11.6
No. 7	4.8	4.4	6.0	6.4	10.0	9.8	13.4	11.9
No. 8	4.7	4.4	6.3	6.4	6.9	9.5	9.8	11.6
No. 9	5.0	4.5	6.5	6.4	6.9	9.2	10.9	11.5
No. 10	3.7	4.4	5.0	6.3	9.5	9.2	9.1	11.3

PERCENTAGE SOFT STONE REMAINING IN SAMPLE AFTER TEST, AVERAGES FOR TEN SAMPLES

Soft Stone	
Placed in Sample, per cent	Remaining After Test, per cent
4	2.0
8	3.3
12	4.5

In these tests, a soft sandstone was added in definite quantities to a quartz gravel to prepare four aggregates containing 0, 4, 8, and 12 per cent soft material. Each material, both the hard and soft, was graded uniformly from 1 1/2 to 3/8 in. After each aggregate had been prepared, it was mixed thoroughly and ten 1000-g. samples taken for test. The attempt made here was to duplicate conditions which would exist if a sample of graded aggregate were tested by the bag and mallet method.

A summary of the results is given in Table XII. The percentage of loss for each sample tested is given together with a cumulative average. For most aggregates, an average value obtained from tests of three samples is very nearly the same as the average for all ten samples of a kind tested. However, of more importance is the comparison between the amount of soft stone placed in the aggregate, the test result obtained, and the amount of soft stone remaining in the sample after the test. Tests of the base gravel show a loss of 4.4 per cent. The results obtained in tests of the gravel containing 4 per cent of soft stone show 6.3 per cent loss, but 2.0 per cent of soft stone is left in the sample. This 6.3 per cent loss, then, includes 2.0 per cent of soft stone and 4.3 per cent from the quartz gravel.

By a similar method of figuring, the test results for the aggregates containing 8 and 12 per cent of soft stone, include 4.5 and 3.8 per cent, respectively, of the quartz gravel in the loss. Although it is granted that the quartz gravel may contain material of a friable nature, a comparison of the gravel and the sandstone used in these tests indicates that a satisfactory method of test should show a greater recovery of the soft material in the test results. The fact that from 38 to 50 per cent of the soft sandstone placed in the sample remains there after the test shows definitely that the test as made is not satisfactory.

Brass Scratch Test:

One of the chief difficulties in the development of a satisfactory method of test for soft pieces is in trying to unify the conceptions offered by different authorities regarding a proper description of a soft piece. In addition to the various tests described here, many more fanciful tests have been considered and, in some cases, plans for quite elaborate pieces of testing equipment have been prepared. A few of these fanciful tests have been tried, but they did not prove even remotely satisfactory. Possibly we have been trying to make something difficult of a really simple problem. We are concerned with the testing of aggregates to determine the presence and quantity of soft pieces—those which yield easily to physical pressure or are not resistant to cutting or wear.

In all of our efforts, the most simple and direct method is a scratch hardness test. This would not indicate the pieces which are unsound, or lightweight, or highly absorptive; or the pieces of chert which appear to be included by some authorities in

the general classification of soft pieces. It would, however, show which pieces of the sample are actually soft, including those formed of a soft material and those which are so poorly bonded that the separate particles in the piece are easily detached from the mass.

A satisfactory test for scratch hardness has already been used in this investigation. It consists merely of scratching the material under test with a piece of yellow brass as shown in Figure 7. This brass will not scratch limestone of good quality, but it is hard enough to scratch badly weathered materials which may be objectionable for use in concrete. The brass used first in these tests consisted of a 1/4-in. rod which has a Rockwell hardness of about B70. Later in this work, the thought of preparing a pencil with a brass rod replacing the lead was developed. For this purpose, drill rod brass[5] of about 1/16-in. diameter was used. Efforts were made to obtain a Rockwell hardness value for this material, but the rod was too small to secure a satisfactory reading. For the purpose of this test, it is probable that minute distinctions in the hardness of the brass used are of little moment. Possibly it is sufficient to describe the material as hard, yellow brass.

The test consists of separating the aggregate into different sizes down to 3/8 in. and determining the scratch hardness of a representative number of pieces of each size. With material of fairly uniform quality, 10 pieces of a size may be sufficient, but 50 or 100 pieces of a size may be required for heterogeneous materials. The weight of the pieces identified as soft is determined for each size, and a weighted average based on the grading of the sample is computed.

As mentioned above, this test is for soft pieces only. If it is desired to limit the amount of other types of deleterious materials in aggregate, separate mention of these should be made in specifications.

Conclusion

The tests reported here were made in an attempt to develop a rational method of testing aggregates for soft piece content. Although most tests used standard or readily procurable apparatus, some rather fanciful or weird contraptions were designed or actually constructed for this purpose. On the whole, it is believed that a serious attempt has been made to study all different methods of test which could be expected to give information of value.

Of all methods tried, the only one considered suitable for laboratory and field use is the scratch hardness test using a hard, yellow brass scribe. For convenience, a pencil with a brass core is suggested.

Attention is called to the practice among some specification writers of using the soft piece classification as a catch-all for many different types of deleterious substances. If it is desired to limit types of deleterious substances other than soft pieces, these other types should be mentioned specifically and separately from pieces which are merely soft.

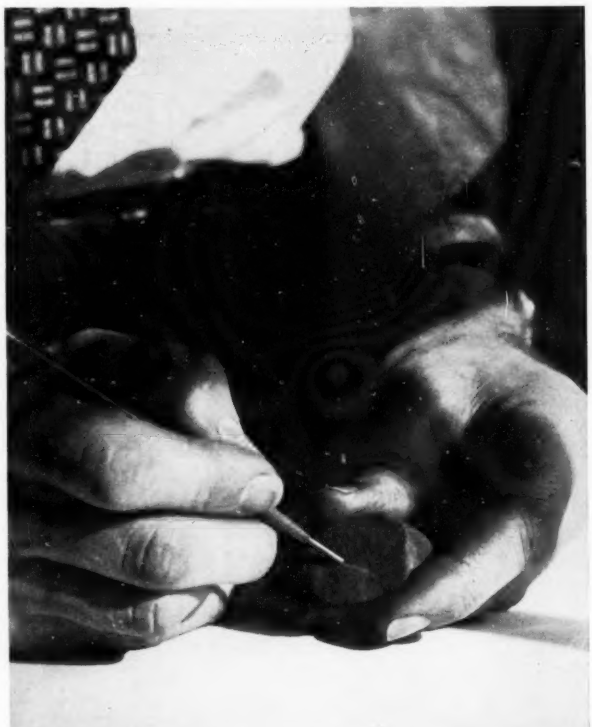

FIGURE 7
Brass Scratch Test

Acknowledgment:

The courtesy of the different state highway departments and the National Sand and Gravel Assn. in furnishing samples for use in these tests is appreciated. Mention is also made of the many valuable suggestions offered by T. R. Smith, and of the assistance furnished by him and the other employees of the Laboratories of the Public Roads Administration.

[5] So called as it is obtainable in the same sizes as steel twist drills

Performance of Airport Pavements[1]

By HENRY AARON

Chief, Paving and Soils Branch
Civil Aeronautics Administration
Washington, D. C.

MANY opinions have been expressed during recent years regarding the performance of airport pavements and its relation to the design requirements as specified by agencies charged with the responsibility for the development of airports. Reference is often made to the fact that under actual service conditions, very thin pavements have been observed to carry very heavy aircraft without damage to pavement or plane. They neglect to give any information regarding the number of such operations or the period of time during which these operations were carried on. There is no reason why any pavement should not be able to handle occasional aircraft considerably heavier than that for which it was designed. In dry weather, an unpaved strip will take almost any type of plane if the operations are not repeated too frequently. However, we must distinguish between the pavement that is safe for an emergency landing or an occasional operation and the pavement required to withstand capacity operations without excessive maintenance.

Failure to recognize significant factors lead to conflicting conclusions that serve only to confuse the situation. It is the purpose of this discussion to bring out certain fundamental facts relative to pavement performance in general, and airport pavements in particular.

First, it should be understood that pavements do not fail suddenly. Pavement failures develop as a result of usage and time.

Secondly, information on the performance of a pavement of a given thickness is of no value unless the soil conditions are described. The character and condition of the soil on which the pavement rests has a greater influence on pavement thickness requirements than any other single factor. For each wheel loading, there is a different thickness of pavement required for each condition of subgrade.

Airport pavements, like all pavements, are subjected to impact, dynamic and static loads. The behavior of the pavements under these loads is influenced by the following operating characteristics:

[1] Presented at the 48th Annual Meeting, American Road Builders' Association, Milwaukee, Wis., March 12-13-14, 1951.

1. When a plane is parked, with its propellers not rotating, the load on the pavement is static and equal to the gross weight of the aircraft. This is the heaviest load imposed on the pavement.
2. The gross load on the pavement is reduced when the plane is standing and the propellers rotating at high speeds.
3. The load transmitted to the pavement decreases as the aircraft begins to taxi and continues to decrease as the taxiing speed increases, equaling zero when the plane becomes airborne.
4. The effects of impact, in a normal landing, may be ignored in pavement design.

Service records have shown definitely that taxiways, aprons, turn-arounds, and warm-up pads at ends of runways are the most critical areas from the standpoint of aircraft use. Pavement failures have occurred on these areas while pavement of the same type and thickness on the runway proper showed no signs of distress. This difference in condition results from the numerous repetitions of loads due to channelization of traffic in these critical areas as compared to the wide distribution of traffic on the runway. This is extremely important in pavement design because of its influence on pavement thickness requirements.

Both flexible and rigid pavements have given satisfactory service on all areas of the airport. It is our experience that the principal requirement is that either type selected must be adequate in thickness to support the expected loads and the construction must meet the standards in quality of materials and workmanship. Failure to comply with these requirements will result in the failures with which everyone has become familiar from experience with highway pavements as well as airport pavements.

Airport pavement condition surveys have revealed the same troubles arising from inadequate design and inferior materials that have been encountered on highway pavements during the past several decades. Serious breakage of both types, correctible only by reconstruction, has been found where pavements were under-designed with respect to thickness or where there was a great increase in loading over that planned in the original design. There are many examples of airport pavements designed for a single wheel load of 15,000 lb. which were later called upon

to carry 30,000-lb. wheel loadings. Obviously, they couldn't take it.

Inferior quality of materials and workmanship has produced the familiar failures, such as spalling, checking, scaling, and disintegration in rigid pavements and rutting, potholing, and loose, unbonded surfaces in flexible pavements.

Operation of turbine-powered aircraft has raised many questions concerning the performance of airport pavements subjected to fuel spillage and high exhaust temperatures. These factors are still under observation but it is generally agreed that spillage is not a serious problem. It has been observed that dense graded, asphaltic concrete offers excellent resistance under normal operating conditions. Also, the use of tar in bituminous mixtures and in seal coats makes them even more resistant. Bituminized rubber compounds seem to give the best service as joint sealers in portland cement concrete pavements.

The effect of the jet blast, however, needs further study. One thing is apparent from observations on fields where jet aircraft operations are of sufficient importance to furnish performance data. The areas seriously affected are small in extent and are almost entirely confined to locations where power checks are made. In these locations, the pavement is subjected to sustained blasts of 5 to 10 minutes duration. This has caused serious erosion of bituminous pavements and has blasted out the sealing material in the joints of rigid pavements.

Except for short sections at the ends of runways and on taxiways where the aircraft enter the runway, there is no damage whatever to runway and taxiway pavements. Furthermore, at these locations the surface defects caused by the blast are of a minor nature.

Another significant fact is that the effects will depend on the design of the aircraft with respect to velocity and temperature of the blast and the angle of the exhaust. As the angle of the blast approaches the horizontal the less important it becomes as far as pavements are concerned.

Finally, it should be remembered that any conclusions we reach regarding the performance of pavements under the operation of jet aircraft must be qualified as tentative and subject to change as new models of aircraft are developed.

In concluding this discussion, it should be emphasized that studies of pavement performance serve as the best guide to pavement design. Therefore, it is necessary to take into consideration all influencing factors before drawing conclusions. Hasty conclusions based on superficial observations can be very detrimental to the development of adequate design standards. It may be added that recent pavement condition surveys indicate that the design requirements presently in use by aviation agencies are not over-conservative.

Highway Congress Will Discuss Road Deficiencies

THE seriously evident need for improvement and rehabilitation of the main highway routes of the nation, with special emphasis on critical deficiencies that could impede the national defense effort, will face the Fourth Highway Transportation Congress in Washington, next May 6, 7 and 8, 1952, Arthur C. Butler, Director of the National Highway Users Conference recently stated.

Sessions of the Congress will be held in the Mayflower Hotel, Washington, D. C., scene of the Third Highway Transportation Congress in 1950. Presiding will be Albert Bradley, Chairman of National Highway Users Conference, Washington, D. C., and Executive Vice President of General Motors.

Like its three predecessors, this Fourth Congress will bring to the nation's capital hundreds of highway transportation leaders representing road user groups in the states; farm organizations; motor clubs; highway officials; bus and truck associations; and every industry which is allied with the continued progress of highway transportation throughout the United States.

The biennial Congresses, sponsored by the National Highway Users Conference, were instituted in 1946 to consolidate, by open discussion, the ideas of all who are concerned with the welfare of over-the-road transportation and to reach a unanimity of purpose in finding solutions to the problems in this field confronting the nation as a whole.

As defense mobilization moves into high gear, decisions are being made daily by government officials which affect every segment of our economy. When the Fourth Highway Transportation Congress convenes, sufficient time will have elapsed to permit a more thorough evaluation of the impact of those decisions upon millions of highway users and upon those who provide their vehicles, highways, fuel, supplies and services.—*Highway Highlights, National Highway Users Conference, Washington, D. C.*

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Eagle Iron Works
129 Holcomb Ave., Des Moines 13, Iowa
Fine Material Screw Washers—Classifiers—Dehydrators; Coarse Material Screw and Log Washers—Dewaterers; Water Scalping and Fine Material Settling Tanks; and "Swintek" Screen Chain Cutter Dredging Ladders

Easton Car and Construction Co.
Easton, Pa.
Off-Highway Transportation: Dump Trailers, Truck Bodies, and Cars for Mines, Quarries, and Earth Moving Projects

Ensign-Bickford Co.
Simsbury, Conn.
Primacord-Bickford Detonating Fuse and Safety Fuse

Euclid Road Machinery Co.
1361 Chardon Road, Cleveland 17, Ohio
Heavy-Duty Trucks and Dump Trailers for "Off-Highway" Hauls, Loaders for Earth Excavation

Even Spread Co.
P. O. Box 87, Owensville, Ohio
Power Spreaders and Attachments for Agricultural Lime and Fertilizer

Flexible Steel Lacing Co.
4607 Lexington St., Chicago 44, Ill.
Flexco HD Belt Fasteners, Alligator Belt Lacing, Flexco Hinged Belt Fasteners, Alligator Belt Cutters, Alligator Wide Belt Cutters, Alligator V Belt Fasteners, Flex V Belt Fasteners

Frog, Switch & Mfg. Co.
Carlisle, Pa.
Manganese Steel Department—Manufacturers of "Indian Brand" Manganese Steel Castings for Frogs, Switches, and Crossings, Jaw and Gyratory Crushers, Cement Mills, Mining Machinery, Etc., Steam Shovel Parts

General Electric Co.
1 River Road, Schenectady 5, N. Y.
Electric Motors, Controls, Locomotives, Coordinated Electric Drives for: Shovels, Drag Lines, Conveyors, Hoists, Cranes, Crushers, Screens, Etc.; Coordinated Power Generating and Distributing Systems Including Turbine Generators, Switchgear, Transformers, Cable, Cable Skids, Load Center Substations

Gill Rock Drill Co.
Lebanon, Pa.
Well Drill Tools and Supplies

Goodrich, B. F., Co.
500 South Main St., Akron 18, Ohio
Industrial Rubber Products — Flexible Bonded Edge Conveyor and Elevator Belting, Cord Conveyor Belting, Highflex and Cord Transmission Belting; Grommet V-Belts; Type 54 Air Hydraulic Control, Burst Proof Steam, Water, Suction and Other Hose; Armorite Chute Lining; Rubber and Koroseal Protective Clothing and Footwear; Tires and Tubes (Automobile, Truck, Off-the-Road, Industrial), Batteries

Goodyear Tire & Rubber Co., Inc.
Akron 16, Ohio
Airfoam; Mechanical Goods—Belting (Conveyor, Elevator, Transmission), Hose (Air Water, Steam, Suction, Miscellaneous), Chute Lining (Rubber); Rims (Truck and Tractor); Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road, LifeGuard, Safety Tubes, Puncture Seal Tubes

Gruendler Crusher and Pulverizer Co.
2915 N. Market St., St. Louis 6, Mo.
Rock and Gravel Crushing and Screening Plants, Jaw Crushers, Roll Crushers, Hammermills, Lime Pulverizers

Gulf Oil Corp. Gulf Refining Co.
Gulf Bldg., Pittsburgh 19, Pa.
Lubricating Oils, Greases, Gasoline and Diesel Fuels

Haiss, George, Mfg. Co., Inc., Division Pettibone Mulliken Corp.
141st-144th on Park Ave., New York 51, N. Y.
Bucket Loaders, Buckets, Portable and Stationary Conveyors, Car Unloaders

Manufacturers Division—National Crushed Stone Association
(continued)

Harnischfeger Corp.
4400 W. National Ave., Milwaukee 14, Wis.
A complete line of Power Excavating Equipment, Overhead Cranes, Hoists, Smootharc Welders, Welding Rod, Motors and Generators, Diesel Engines

HarriSteel Products Co.
420 Lexington Ave., New York 17, N. Y.
Woven Wire Screen Cloth

Hayward Co.
50 Church Street, New York 7, N. Y.
Orange Peel Buckets, Clam Shell Buckets, Electric Motor Buckets, Automatic Take-up Reels

Heidenreich, E. Lee, Jr., Consulting Engineers
67 Second St., Newburgh, N. Y.
Plant Layout, Design, Supervision; Open Pit Quarry Surveys; Appraisals—Plant and Property

Hendrick Mfg. Co.
Carbondale, Pa.
Perforated Metal Screens, Perforated Plates for Vibrating, Shaking, and Revolving Screens; Elevator Buckets; Test Screens; Wedge Slot Screens; Open Steel Floor Grating

Hercules Powder Co.
Wilmington 99, Del.
Explosives and Blasting Supplies

Hetherington & Berner Inc.
701-745 Kentucky Ave., Indianapolis 7, Ind.
Asphalt Paving Machinery, Sand and Stone Dryers, Dust Collectors

Hewitt-Robins Incorporated
370 Lexington Ave., New York 17, N. Y.
Belt Conveyors (Belting and Machinery); Belt and Bucket Elevators; Car Shake-outs; Feeders; Industrial Hose; Screen Cloth; Sectional Conveyors; Skip Hoists; Stackers; Transmission Belting; Vibrating Conveyors, Feeders, and Screens; Design and Construction of Complete Plants

Illinois Powder Mfg. Co.
506 Olive St., St. Louis 1, Mo.
Gold Medal Explosives

Ingersoll-Rand Co.
11 Broadway, New York 4, N. Y.
Rock Drills, Quarrymaster Drills, Jackbits, Bit Reconditioning Equipment, Portable and Stationery Air Compressors, Air Hoists, Slusher Hoists, Air Tools, Diesel Engines, Pumps

Insley Manufacturing Corp.
801 N. Olney St., Indianapolis 6, Ind.
Concrete Carts and Buckets, ½ Yd. Cranes and Shovels

Iowa Manufacturing Co.
916 16th St., N.E., Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Hot and Cold Mix Asphalt Plants, Stabilizer Plants, KU-BIT Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills

Jaeger Machine Co.
550 W. Spring St., Columbus 16, Ohio
Portable and Stationary Air Compressors, Self-Priming Pumps, Truck Mixers, Concrete Mixers, Road Paving Machinery, Hoists and Towers

Jaite Co.
Jaite, Ohio
Multiwall Paper Bags, Sewn and Pasted Style for Packaging Lime, Cement, Plaster, Etc.

Jeffrey Manufacturing Co.
E. First Ave., Columbus 16, Ohio
Material Handling Machinery, Crushers, Pulverizers, Screens, Chains

Johnson-March Corp.
1724 Chestnut St., Philadelphia 3, Pa.
Dust Allaying Equipment

Joy Manufacturing Co.
333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.
Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, and Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists; Multi-Purpose and Portable Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; Drill-Bit Furnaces; "Spaders"; "String-a-Lite" (Safety-Lighting-Cable); Backfill Tampers; Drill Bits: Rock and Core

Kennedy-Van Saun Mfg. and Eng. Corp.
2 Park Ave., New York 16, N. Y.
Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel Co.
505 Kensington Ave., Chicago 28, Ill.
Manganese Steel Castings, Dipper Teeth, Crawler Treads, Jaw Plates, Concaves and Hammers

Keystone Driller Co.
2001-2021 Eighth Ave., Beaver Falls, Pa.
Drills, Power Shovels

King Powder Co., Inc.
Cincinnati, Ohio
Detonite, Dynamites, and Blasting Supplies

Manufacturers Division—National Crushed Stone Association
(continued)

Koehring Co.
3026 W. Concordia Ave., Milwaukee 16, Wis.
Excavating, Hauling and Concrete Equipment

Kraft Bag Corp.
630 Fifth Ave., New York 20, N. Y.
Heavy Duty Multiwall Paper Bags

Link-Belt Co.
300 West Pershing Road, Chicago 9, Ill.
Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, Speed-O-Matic Shovels—Cranes—Draglines and Power Transmission Equipment

Ludlow-Saylor Wire Co.
634 S. Newstead Ave., St. Louis 10, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, All Commercial Alloys and Metals

Mack Manufacturing Corp.
350 Fifth Ave., New York 1, N. Y.
On- and Off-Highway Trucks, Tractor Trailers, Six-Wheelers, from 5 to 30 Tons Capacity, both Gasoline- and Diesel-Powered

Marion Power Shovel Co.
617 W. Center St., Marion, Ohio
A Complete Line of Power Shovels, Draglines, and Cranes

Marsh, E. F., Engineering Co.
4324 W. Clayton Ave., St. Louis 10, Mo.
Plant Design, Engineering Service, Complete Pit and Quarry Equipment

McLanahan & Stone Corp.
200 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment —Crushers, Washers, Screens, Feeders, etc.

Michigan Power Shovel Co.
270 Miller St., Benton Harbor, Mich.
Truck Mounted and Crawler Shovel Crane 3/8 and 1/2 Cu. Yd.

Murphy Diesel Co.
5317 W. Burnham St., Milwaukee 14, Wis.
Murphy Diesel Engines Ranging from 90 to 190 Continuous Horsepower at 1200 Rpm. and Packaged Type Generator Sets 60 to 133 Kw. for All Classes of Service

Nelson, N. P., Iron Works, Inc.
820 Bloomfield Ave., Clifton, N. J.
Nelson Bucket Loaders

Nordberg Mfg. Co.
3073 S. Chase Ave., Milwaukee 7, Wis.
Cone, Gyratory, Jaw and Impact Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens; Grizzlies; Diesel and Steam Engines; Compressors; Mine Hoists; Track Maintenance Tools

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 S. LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels

Osgood Co.
Cheney Ave., Marion, Ohio
Power Shovels, Cranes, Draglines, Hoes, Etc., 3/8 to 2 1/2 Cu. Yd.

Pennsylvania Crusher Co.
Liberty Trust Bldg., Broad and Arch Sts., Philadelphia 7, Pa.
Single Roll Crushers, Impactors, Hammermills, Ring Type Granulators, KUE-KEN Jaw Crushers, KUE-KEN Gyracones, Dixie Non-Clog and Standard Hammermills

Pettibone Mulliken Corp.
4710 W. Division St., Chicago 51, Ill.
Buckets, Dragline and Parts; Loaders—Car, Bucket; Plants—Asphalt, Portable

Pioneer Engineering Works, Inc.
1515 Central Ave., N. E., Minneapolis 13, Minn.
Jaw Crushers, Roll Crushers (Twin and Triple), Vibrating and Revolving Screens, Feeders (Mechanical, Grizzly, Apron, and Pioneer-Oro), Belt Conveyors, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants

Pit and Quarry Publications
431 S. Dearborn St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook

Quaker Rubber Corp.
Tacony and Milnor Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Rock Bit Sales and Service Co.
350 Depot St., Asheville, N. C.
Tungsten Carbide Detachable Bits, "Rock Bit" Drill Steel Inlaid with Tungsten Carbide, Carbon Hollow Drill Steel, Alloy Hollow Drill Steel

Manufacturers Division—National Crushed Stone Association
(concluded)

Rock Products
309 West Jackson Blvd., Chicago 6, Ill.

Roebling's, John A., Sons Co.
Woven Wire Fabrics Division
P. O. Box D, Roebling, N. J.
Aggregate Screen, Hardware and Industrial Wire Cloth, Insect Screening, Wire Rope, Fittings and Strand, Slings, Suspension Bridges and Cables, Aerial Wire Rope Systems, Ski Lifts, Electric Wire and Cable, Magnet Wire

Sanderson-Cyclone Drill Co.
South Main St., Orrville, Ohio
All Steel Wire Line, Air Speed Spudders, Large Blast Hole Drills, Drilling Tools and Drilling Supplies

Schield Bantam Co.
Waverly, Iowa
Bantam Trench Hoes, Draglines, Clams, Shovels

Screen Equipment Co.
1754 Walden Ave., Buffalo 25, N. Y.
SECO Vibrating Screens

Shaped Charge Explosive Manufacturers, Inc.
P. O. Box 900, Martinsburg, W. Va.
Shaped Charge Explosives for Industrial Rock Reduction

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screen, Simplicity D'centegrator, Simplicity D'watering Wheel

Smith Engineering Works
532 E. Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman Foundry & Machine Co., Inc.
Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Elevators, Feeders, Car Pullers, Screens, Skip Hoists, Complete Plants

Talcott, W. O. & M. W., Inc.
91 Sabin St., Providence 1, R. I.
Belt Fasteners, Belt Lacing, Conveyor Belt Fasteners, and Patch Fasteners

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and other Special Alloy Steel Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
Power Shovels, Cranes, Crawler Cranes, Locomotive Cranes, Draglines, Diesel Electric, Gasoline, 3/8 to 2 1/2 Cu. Yd. Capacities

Torrington Co.
Bantam Bearings Division
3702 W. Sample St., South Bend 21, Ind.
Anti-Fricition Bearings; Roller Bearings: Spherical, Tapered, Straight, Ball, Needle

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 N. 7th St., Allentown, Pa.
Explosives and Blasting Supplies

Tyler, W. S., Co.
3615 Superior Ave., N. E., Cleveland 14, Ohio
Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers and Tyler Standard Screen Scale Sieves

Universal Engineering Corp.
625 C Ave., N. W., Cedar Rapids, Iowa.
Jaw Crushers, Roll Crushers, Hammermills, Complete Crushing, Screening, and Loading Plants, Either Stationary or Portable for Stone Aggregates or Aglime

Vibration Measurement Engineers
7705 Sheridan Rd., Chicago 26, Ill.
Specialists in Blasting Complaint Investigations; Seismological Surveying; Expert Testimony in Blasting Litigation